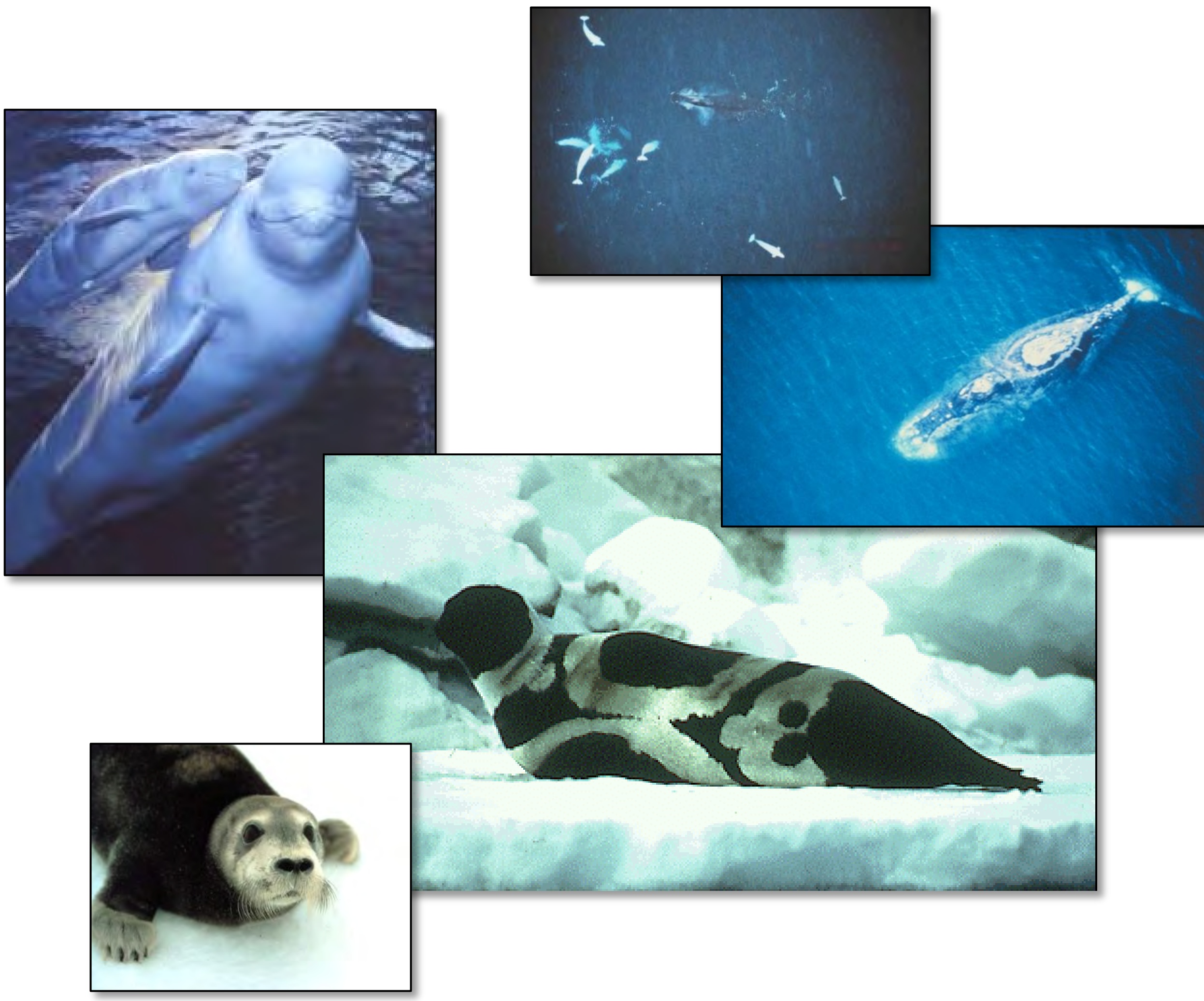
Effects of Oil and Gas Activities in the Arctic Ocean

Final Environmental Impact Statement

Volume 1: Chapters 1-3



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United States Department of Commerce
National Oceanic and Atmospheric Administration
National Marine Fisheries Service
Office of Protected Resources

EXECUTIVE SUMMARY

1.0 INTRODUCTION

The U.S. Department of Commerce, National Oceanic and Atmospheric Administration (NOAA), National Marine Fisheries Service (NMFS) has prepared this Environmental Impact Statement (EIS) to describe the effects of offshore oil and gas exploration activities in the U.S. Beaufort and Chukchi seas, Alaska. This EIS analyzes a range of management alternatives to assist NMFS in carrying out their statutory responsibilities to authorize or permit these activities. The U.S. Department of the Interior Bureau of Ocean Energy Management (BOEM) participated in the preparation of this EIS as a cooperating agency.

The agency's statutory responsibilities include BOEM's issuance of permits and authorizations under the Outer Continental Shelf Lands Act (OCSLA) for seismic surveys and concurrence on ancillary activities and NMFS' issuance of incidental take authorizations (ITAs) under Section 101(a)(5) of the Marine Mammal Protection Act (MMPA). A geological and geophysical (G&G) permit must be obtained from BOEM in order to conduct G&G exploration activities for oil, gas, and sulphur resources when operations occur on unleased lands or on lands leased to a third party.

NMFS issues ITAs for oil and gas exploration activities because it is likely that seismic and exploratory drilling activities will result in the disturbance of marine mammals through sound, discharge of pollutants, and/or the physical presence of vessels. Because of the potential for these activities to "take" marine mammals, oil and gas operators may choose to apply for an ITA.

1.1 Background

On April 6, 2007, NMFS and the U.S. Minerals Management Service (MMS [now BOEM]) published a Draft Programmatic EIS (DPEIS) that assessed the impacts of MMS' issuance of permits and authorizations for seismic surveys in the Beaufort and Chukchi seas off the coast of Alaska, and NMFS' issuance of ITAs to take marine mammals incidental to conducting those permitted activities. Since the 2007 DPEIS was published, new information that alters the scope, set of alternatives, and analyses in the DPEIS has become available. In addition, NMFS determined that an EIS must also address the potential effects of exploratory drilling, which were not addressed in the 2007 DPEIS. Therefore, MMS and NMFS filed a Notice of Withdrawal of the DPEIS on October 28, 2009, and announced their decision to prepare a new EIS to be called, *Effects of Oil and Gas Activities in the Arctic Ocean,* with BOEM as a cooperating agency.

On December 30, 2011, NMFS published a Notice of Availability for the *Effects of Oil and Gas Activities in the Arctic Ocean Draft Environmental Impact Statement* in the *Federal Register* (76 FR 82275). The public was afforded 60 days to comment on that document. Consistent with comments on the Draft EIS, NMFS and BOEM determined that the environmental analysis would benefit from the inclusion of an additional alternative for analysis that covers a broader range of potential levels of exploratory drilling, including scenarios in the Beaufort and Chukchi seas that are more reflective of the levels of activity that oil and gas companies have indicated may be pursued in the region within the coming years and that some of the alternatives should be slightly altered from the 2011 Draft EIS. The alternatives are based upon the agencies' analysis of additional information, including the comments and information submitted by stakeholders during the Draft EIS public comment period. For this reason, the agencies determined it appropriate to prepare a Supplemental Draft EIS and allow for an additional public comment period before releasing the Final EIS (FEIS) and Record of Decision (ROD). On January 30, 2013, NMFS published an NOI informing the public of its determination to prepare a Supplemental Draft EIS in the *Federal Register* (78 FR 6303).

NMFS made several substantive changes to this FEIS since publication of the 2013 Supplemental EIS. Portions of the EIS where substantive changes have occurred include:

- Alternatives
  - Based on updated data, modified some of the time/area closures, which have been identified as areas in which activities could be limited in order to protect marine mammals during times when key life functions are being performed (e.g., feeding) and subsistence hunting areas from the effects of exploration activities.
- Mitigation Measures
  - Updated the structure and analysis of the mitigation measures contemplated for inclusion under the alternatives.
  - For each measure, outlined activities to which it applies (e.g., just 2D/3D seismic surveys or just exploratory drilling or all activities), the purpose of the measure, the science, support for reduction of impacts to marine mammals or subsistence availability of marine mammals, the likelihood of effectiveness, the history of implementation of the measure, practicability for applicant implementation, and recommendation for how, and if, to apply the measure in future MMPA ITAs.
  - Added a section outlining the mitigation measures that were considered but are no longer carried forward for inclusion in future MMPA ITAs.
- Baseline Information
  - Using data and literature noted by commenters during the previous public comment period, updated information in the affected environment sections to incorporate newer information (mostly for marine mammals and subsistence activities).
- Impact Analyses
  - Revised the impact criteria and analyses of potential impacts to marine mammals to include additional factors that more closely align with analyses conducted under the MMPA.
  - Included information regarding the final acoustic injury thresholds used by NOAA to determine the level at which injury of marine mammals occurs.
  - NMFS conducted a first-order assessment of chronic and cumulative effects of sound on marine mammals in response to public comments on the DEIS and SEIS and report the initial results as they relate to different scenarios addressed across the EIS Alternatives.

NMFS has made several changes to the document based on public comments received on the 2011 Draft EIS and the 2013 Supplemental Draft EIS. A summary of the comments and our responses to those comments can be found in Appendix A of this FEIS.

1.2 Process

NMFS, as the lead federal agency, prepared this EIS to evaluate a broad range of reasonably foreseeable levels of exploration activities that may occur. BOEM and the North Slope Borough (NSB) (a local government entity of the State of Alaska) served as formal cooperating agencies; the Environmental Protection Agency (EPA) served as a consulting agency. NMFS also coordinated with the Alaska Eskimo Whaling Commission (AEWC) pursuant to our co-management agreement under the MMPA on the preparation of this EIS. NMFS invited the U.S. Fish and Wildlife Service (USFWS) to join the effort as a cooperating agency, but they declined the request; however, USFWS participated as a "consulting" agency in the preparation of this FEIS. NMFS also shared preliminary drafts of the FEIS with the State of Alaska for their review.

NMFS has published this EIS to disclose the potential impacts associated with their issuance of ITAs. The EIS will allow NMFS and BOEM to comprehensively assess activities that may occur in a given season before receiving applications. This will allow them to issue permits and authorizations more quickly and efficiently.

A brief summary of the agencies' regulatory requirements follows:

1.2.1 MMPA Requirements

Sections 101(a)(5)(A) and (D) of the MMPA (16 United States Code [U.S.C.] § 1361 *et seq.*) direct the Secretary of Commerce to allow, upon request, the incidental, but not intentional taking of small numbers of marine mammals by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographical region, if certain findings are made and either regulations are issued or, if the taking is limited to harassment, a notice of proposed authorization is provided to the public for review. Authorization for incidental takings shall be granted if:

- NMFS finds that the taking will have a negligible impact on the species or stock(s);
- NMFS finds that the taking will not have an unmitigable adverse impact on the availability of the species or stock(s) for subsistence uses (where relevant); and
- the permissible methods of taking and requirements pertaining to the mitigation, monitoring, and reporting of such takings are set forth.

1.2.2 Outer Continental Shelf Lands Act Requirements:

The OCSLA, 43 U.S.C. § 1331 et seq. prescribes a four stage process for development of OCS federal oil and gas resources: (1) a 5-year oil and gas leasing program; (2) lease sales; (3) ancillary activities and exploration; and (4) development and production. Environmental reviews are conducted for each of these stages.

The OCSLA directs BOEM and the Bureau of Safety and Environmental Enforcement (BSEE) to oversee the "expeditious and orderly development [of OCS resources] subject to environmental safeguards" (43 U.S.C. §§ 1332(3), (6), 1334(a)(7)). Critical to the potential development of OCS resources is the ability to gather geological and geophysical data on the resource potential of the OCS. BOEM, which has rights to all data collected under the OCSLA and implementing regulations, needs the best available data to ensure that the federal government, i.e., the American people, receives fair market value for leased resources. The OCSLA establishes U.S. Department of Interior authority, delegated to BOEM by regulation, to issue permits for G&G, concur on notices of ancillary activities, and approve exploratory drilling plans for these and related purposes. BOEM's regulations for G&G permits are at 30 CFR Part 551 and for ancillary activities and Exploration Plans are at 30 CFR Part 550. Exploration drilling activities require a permit from BSEE (Application for Permit to Drill under 30 CFR Part 250).

BOEM regulations (30 CFR Part 551) specifically state that such activities cannot:

- interfere with or endanger operations under any lease or right-of-way, easement, right-of-use, Notice, or permit issued or maintained under the OCSLA;
- cause harm or damage to life (including fish and other aquatic life), property, or to the marine, coastal, or human environment;
- cause harm or damage to any mineral resource (in areas leased or not leased);
- cause pollution;
- create hazardous or unsafe conditions;

- disturb archaeological resources; or
- unreasonably interfere with or cause harm to other uses of the area.

Pursuant to 30 CFR Part 551.4, a G&G permit must be obtained from BOEM to conduct G&G exploration for oil, gas, and sulphur resources when operations occur on unleased lands or on lands leased to a third party. Ancillary activities are regulated under 30 CFR Part 550.207 through 550.210, which also states that a notice must be submitted before conducting such activities pursuant to a lease issued or maintained under the OCSLA.

1.3 Proposed Action and Project Area

The proposed actions of two federal agencies considered in this EIS are:

- The issuance of ITAs under Section 101(a)(5) of the MMPA, by NMFS, for the incidental taking of marine mammals during G&G permitted activities, ancillary activities, and exploratory drilling activities in the U.S. Beaufort and Chukchi seas, Alaska, and
- The authorization of G&G permits and concurrence on ancillary activities in the U.S. Beaufort and Chukchi seas, Alaska, by BOEM under the OCSLA.

These federal actions are related, but distinct, actions.

This EIS will also evaluate the potential effects to the environment of authorizing takes of marine mammals incidental to such activities occurring in either federal or State of Alaska waters. Activities that could occur in state waters include on-ice and open water seismic surveys, high-resolution site clearance/shallow hazards surveys, and exploratory drilling.

The spatial scope of this EIS is limited to the Arctic from the border between the U.S. and Canada in the Beaufort Sea to Nome in the Bering Sea. This spatial extent includes the areas where seismic surveys, ancillary activities, and exploratory drilling may occur in the U.S. Arctic, as well as vessel transit routes through the Bering Strait and staging and possible resupply ports.

1.4 Purpose and Need

1.4.1 Purpose

Energy use in the U.S. is expected to continue to increase from present levels through 2040 and beyond (EIA 2015). For example, the U.S. consumption of crude oil and petroleum products has been projected to increase from about 19 million barrels (Mbbl) per day in 2013, to about 19.6 Mbbl per day in 2020, then decline to 19.3 Mbbl per day in 2040 (EIA 2015). Oil and gas reserves in the OCS represent significant sources that currently help meet U.S. energy demands and are expected to continue to do so in the future. The benefits of producing oil and natural gas from the OCS include not only helping to meet this national energy need but also generating money for public use. In this context, the purpose for issuing permits for seismic surveying activities under the OCSLA and issuing authorizations to "take" marine mammals under the MMPA are discussed below.

The federal actions considered in this EIS are the issuance of G&G permits and ancillary activity notice approvals by BOEM for the Beaufort and Chukchi seas and the issuance of ITAs under the MMPA for G&G surveys, ancillary activities, and exploratory drilling activities in the Beaufort and Chukchi seas by NMFS. ITAs could be issued for these activities in either federal or State of Alaska waters. Given the widespread presence of several species of marine mammals in the Beaufort and Chukchi seas and the nature of oil and gas exploration activities, it is likely that some amount of seismic and exploratory drilling activities will result in the disturbance of marine mammals through sound, discharge of

pollutants, and/or the physical presence of vessels. Because of the potential for these activities to "take" marine mammals, oil and gas operators may choose to apply for an ITA.

Sections 101(a)(5)(A) and (D) of the MMPA direct NMFS to allow, upon request, the incidental, but not intentional, taking of small numbers of marine mammals of a species or population stock by U.S. citizens who engage in a specified activity (other than commercial fishing) within a specified geographical region if certain findings are made and either regulations are issued or, if the taking is limited to harassment, a notice of proposed authorization is provided to the public for review. Authorization for incidental taking shall be granted if NMFS finds that the taking will have a negligible impact on the affected species or stock(s) and will not have an unmitigable adverse impact on the availability of the species or stock(s) for taking for subsistence uses. NMFS must also prescribe: the permissible methods of taking pursuant to the activity; other means of effecting the "least practicable adverse impact" on the affected species or stock and its habitat and on the availability of such species or stock for subsistence uses; and requirements pertaining to the monitoring and reporting of such taking.

NMFS' decision to prepare an EIS should not be construed as an assumption that significant adverse effects would occur from all levels of activities analyzed. Federal agencies may employ the EIS process to aid in their decision-making, whether the contemplated action would have significant effects or not. In this case, the primary reason for preparing an EIS was, that the higher levels of activity predicted by the oil and gas industry to likely occur in the near future could have significant cumulative impacts (we note that predictions of activity levels are likely lower now, in 2016, than they were when the EIS scoping process started in 2010). Based on the industry's prediction of increased activities, NMFS and BOEM wanted to ensure that appropriate NEPA analysis was completed, rather than wait until the first year that anticipated cumulative impacts from industry activities exceed the significance threshold and delay activities while an EIS was written. This EIS was written to prevent permitting delays from causing a future gap in activities.

1.4.2 Need

NMFS expects to receive applications to take marine mammals incidental to oil and gas industry exploration activities (i.e., G&G and ancillary surveys and exploratory drilling) pursuant to Sections 101(a)(5)(A) and (D) of the MMPA. This EIS is intended to assist NMFS in its MMPA decision-making process related to projected requests for ITAs by providing a comprehensive understanding of deep penetration geophysical surveys, shallow hazards surveys, and exploratory drilling in the U.S Beaufort and Chukchi seas for future years and may be revised as necessary. NMFS intends to use this EIS as the required NEPA analysis to support the issuance of ITAs for Arctic oil and gas exploration activities. It is the intent of NMFS that the scope of this EIS covers as many actions as possible. However, if necessary, NMFS may need to conduct additional NEPA analysis to support future Arctic MMPA oil and gas permit decisions if such activities fall outside the scope of this EIS. This applies to actions taken under Sections 101(a)(5)(A) and (D) (i.e., issuance of LOAs and IHAs) Please see Chapter 5 (Sections 5.1.2 and 5.1.3) for additional discussions on NEPA compliance related to this EIS.

1.5 Public Input Process

1.5.1 Scoping

The scoping period for the *Effects of Oil and Gas Activities in the Arctic Ocean EIS* began on February 8, 2010 and ended April 9, 2010. Public scoping meetings were held during February and March 2010 in the communities of Kotzebue, Point Hope, Point Lay, Wainwright, Barrow, Nuiqsut, Kaktovik, and Anchorage. Scoping comments were received verbally and in writing through discussion, testimony, fax, regular mail, and electronic mail.

Of the issues identified during scoping, those that were most commonly raised included:

- Concerns regarding the NEPA process;
- Impacts to marine mammals and habitats;
- Occurrence of oil spills;
- Climate change;
- Protection of subsistence resources and the Iñupiat culture and way of life;
- Availability of research and monitoring data for decision-making;
- Monitoring requirements; and
- Suggestions for, or implementation of, mitigation measures.

For more detail on the issues raised during the scoping process, please refer to Appendix C in the 2011 Draft EIS.

Executive Order 13175 (*Consultation and Coordination with Indian Tribal Governments*), states that the U.S. Government will "*work with Indian tribes on a government-to-government basis to address issues concerning Indian Tribal self-government, trust resources, and Indian Tribal treaty and other rights.*" For government-to-government consultation during the scoping process for this EIS, Tribal governments in each community, with the exception of Anchorage, were notified of the EIS process and invited to participate. The Tribal Organizations that received invitations to participate are listed below. Native Village of Point Hope declined to participate because they received less than one month of prior notification.

- Native Village of Nuiqsut
- Iñupiat Community of the Arctic Slope
- Native Village of Point Hope
- Native Village of Point Lay
- Native Village of Barrow
- Native Village of Wainwright
- Native Village of Kotzebue

1.5.1 Draft EIS Public Comment Process

The public comment process for the 2011 Draft EIS began on December 30, 2011. After granting a 15-day extension, the comment period ended on February 28, 2012. Public meetings were held in the communities of Barrow, Wainwright, Kotzebue, Kivalina, Point Hope, and Anchorage. Public comments were received verbally and in writing through discussion, testimony, fax, regular mail, and electronic mail.

Of the issues raised during the 2011 Draft EIS public comment process, many were similar to those mentioned above as raised during the scoping process. Those that were most commonly raised include:

- Concerns related to public participation and review process;
- Compliance with NEPA, the MMPA, and other applicable statutes;
- Inadequacy with the range of alternatives;
- Improper dismissal of alternatives;
- Inadequacy of description and analysis of certain physical, biological, and social resources and failure to include newer data; and
- Insufficient analysis and information related to the effectiveness and implementation of mitigation measures.

1.5.2 Supplemental EIS Public Comment Process

The public comment process for the 2013 Supplemental EIS began on March 29, 2013. After granting a 30-day extension, the comment period ended on June 27, 2013. Public meetings were held in the communities of Kotzebue, Barrow, and Anchorage. Public comments were received verbally and in

writing through discussion, testimony, fax, regular mail, and electronic mail. The issues raised during public comment on the 2013 Supplemental EIS did not differ from the issues raised during the scoping process and the public comment period for the 2011 Draft EIS.

2.0 ALTERNATIVES

A total of 12 alternatives were initially considered for this FEIS, with the No Action Alternative and five action alternatives carried forward for analysis. The alternatives dismissed and not considered for analysis include: permanent closures of areas, caps on levels of activity and/or noise, duplicative surveys, zero discharge, an alternative that employs adaptive management approaches, activity levels likely to follow a discovery including future lease sales. Some aspects of the dismissed alternatives have been incorporated into the five remaining action alternatives and/or mitigation measures to be considered for analysis.

NMFS and BOEM identified alternatives by:

- Evaluating alternative concepts suggested during the scoping period (such as using alternative technologies to airguns for seismic surveys);
- Reviewing potential alternatives in the context of NMFS and BOEM's regulatory requirements;
- Assessing potential levels of seismic exploration and exploratory drilling activities, and a suite of Standard Mitigation Measures; and
- Identifying a range of potential Additional Mitigation Measures that need further analysis and may be applied to alternatives pursuant to the MMPA ITA process and the BOEM OCSLA permitting process.

Alternatives were developed based on NMFS' desire to proactively analyze both the effects of multiple exploration activities and effectiveness of mitigation measures, and to anticipate regulatory compliance needs over the timeframe of this EIS.

Past ITAs have been issued for individual G&G surveys, ancillary activities, and exploratory drilling projects in the Beaufort and Chukchi seas in the form of Incidental Harassment Authorizations (IHAs) for periods of no more than one year at a time. This EIS analyzes the effects from multiple oil and gas industry exploration activities, the potential effects of authorizing takes from concurrent activities, and whether the standard mitigation and monitoring measures stipulated in the past are appropriate for current and reasonably foreseeable oil and gas activities. The analysis also includes additional mitigation measures suggested by the public or other agencies.

Based upon past lease sales, G&G permits, ancillary activity notices, exploration drilling exploration activities, and requests for ITAs, NMFS and BOEM have determined a reasonable range and level of activities for which permits and authorizations may be requested in the foreseeable future. While the level of activity proposed may vary from one year to the next, the action alternatives represent a reasonable range of exploration activities for which permits and authorizations may be requested.

In this EIS, NMFS and BOEM present and assess a reasonable range of G&G, ancillary, and exploratory drilling activities expected to occur, as well as a reasonable range of mitigation measures, in order to accurately assess the potential consequences of issuing ITAs under the MMPA and permits under the OCSLA.

The six alternatives evaluated are:

- **Alternative 1:** No Action
- **Alternative 2:** Authorization for Level 1 Exploration Activity
- **Alternative 3:** Authorization for Level 2 Exploration Activity

- **Alternative 4:** Authorization for Level 3 Exploration Activity
- **Alternative 5:** Authorization for Level 3 Exploration Activity with Additional Required Time/Area Closures
- **Alternative 6:** Authorization for Level 3 Exploration Activity with Use of Alternative Technologies

Table ES-1 outlines the differences in the alternatives between the 2011 Draft EIS, the 2013 Supplemental Draft EIS, and this FEIS, as well as outlining the differences between the alternatives themselves.

For analysis in this EIS, one "program" entails however many surveys or exploration wells a particular company is planning for that season. Each "program" would use only one source vessel (or two source vessels working in tandem, e.g., ocean-bottom node or cable surveys) or drilling unit (e.g., drillship, jackup rig, SDC) to conduct the program and would not survey multiple sites or drill multiple wells concurrently. Survey vessels and drilling units are generally self-contained, with the crew living aboard the vessel. For surveys and drilling operations in the Beaufort Sea, support operations would likely occur out of West Dock or Oliktok Dock near Prudhoe Bay. Chukchi Sea surveys and drilling operations could be supported either from Wainwright or Nome. Helicopters stationed at either Barrow (for operations in either the Beaufort Sea or Chukchi Sea), Deadhorse (for operations in the Beaufort Sea), or Wainwright (for operations in the Chukchi Sea) would provide emergency or search-and-rescue support, as needed.

Site clearance and shallow hazards survey programs are contemplated in each action alternative and typically also include ice gouge and strudel scour surveys and are often referred to as marine survey programs by oil and gas industry operators. The ice gouge and strudel scour surveys do not involve the use of airguns but do involve the use of smaller, higher-frequency sound sources, such as multibeam echosounders and sub-bottom profilers. The area of a site clearance and shallow hazards survey, which is tied to a lease plan, is typically determined by the number of potential, future drill sites in the area. Table 2.4 outlines the typical types of sound sources used in these programs.

Table ES-1 Differences in the Alternatives between the December 2011 Draft EIS, the March 2013 SDEIS, and the FEIS

Alternative	2011 Draft EIS	2013 Supplemental Draft EIS	2016 FEIS
Alternative 1 (No Action)	NMFS would not issue ITAs under the MMPA, and BOEM would not issue permits and notices under the OCSLA.	Same as in 2011 Draft EIS	Same as in 2011 Draft EIS and 2013 SDEIS
Alternative 2 (Preferred Alternative)	Considered up to: • Four 2D/3D seismic or CSEM surveys in the Beaufort Sea and up to three 2D/3D seismic or CSEM surveys in the Chukchi Sea, with up to one of that total number in each done in-ice, if necessary. • Three site clearance and high resolution shallow hazards survey programs in each sea, per year. • One on-ice seismic survey in the Beaufort Sea, per year. • One exploratory drilling program[1] in each sea, per year. Considered inclusion of required standard mitigation measures and additional mitigation measures.	Same as in 2011 Draft EIS	Same as in 2011 Draft EIS and 2013 SDEIS. However, the suite of required standard mitigation measures and additional mitigation measures has been revised based on public comments.
Alternative 3	Considered up to: • Six 2D/3D seismic or CSEM surveys in the Beaufort Sea and up to five 2D/3D seismic or CSEM surveys in the Chukchi Sea, with up to one of that total number in each done in-ice, if necessary. • Five site clearance and high resolution shallow hazards survey programs in each sea, per year. • One on-ice seismic survey in the Beaufort Sea, per year.	Same as in 2011 Draft EIS	Same as in 2011 Draft EIS and 2013 SDEIS. However, the suite of required standard mitigation measures and additional mitigation measures has been revised based on public comments.

[1] Please see Section 2.4.3 of this FEIS for a discussion of the term "exploratory drilling program."

Alternative	2011 Draft EIS	2013 Supplemental Draft EIS	2016 FEIS
	• Two exploratory drilling programs in each sea, per year. Considered inclusion of required standard mitigation measures and additional mitigation measures.		
Alternative 4	Considered up to: • Six 2D/3D seismic or CSEM surveys in the Beaufort Sea and up to five 2D/3D seismic or CSEM surveys in the Chukchi Sea, with up to one of that total number in each done in-ice, if necessary. • Five site clearance and high resolution shallow hazards survey programs in each sea, per year. • One on-ice seismic survey in the Beaufort Sea, per year. • Two exploratory drilling programs in each sea, per year. Considered inclusion of required standard mitigation measures and additional mitigation measures. Considered inclusion of required time/area closures for specific areas important to biological productivity, life history functions for specific species of concern, and subsistence activities. Areas considered were: • Camden Bay; • Barrow Canyon and the Western Beaufort Sea; • Shelf Break of the Beaufort Sea; • Hanna Shoal; and • Kasegaluk Lagoon/Ledyard Bay Critical Habitat Unit.	This alternative differs from Alternative 4 from the 2011 DEIS in the following ways: • Considers up to four exploratory drilling programs in each sea, per year. • It does not consider inclusion of any required time/area closures. Everything else about the alternative remains the same.	This alternative remains the same as the one presented in the 2013 SDEIS with the exception of the changes made to the suite of required standard mitigation measures and additional mitigation measures based on public comments.

Alternative	2011 Draft EIS	2013 Supplemental Draft EIS	2016 FEIS
Alternative 5	Considered up to: • Six 2D/3D seismic or CSEM surveys in the Beaufort Sea and up to five 2D/3D seismic or CSEM surveys in the Chukchi Sea, with up to one of that total number in each done in-ice, if necessary. • Five site clearance and high resolution shallow hazards survey programs in each sea, per year. • One on-ice seismic survey in the Beaufort Sea, per year. • Two exploratory drilling programs in each sea per year Considered inclusion of required standard mitigation measures and additional mitigation measures. Considered including specific additional measures that focus on the use of alternative technologies that have the potential to augment or replace traditional airgun-based seismic exploration activities.	Alternative 5 in this EIS is similar to Alternative 4 from the 2011 Draft EIS with some slight changes: • Increase in the maximum level of exploratory drilling programs from up to two in each sea, per year to up to four in each sea, per year. • Inclusion of required time/area closures. However, there are changes. Camden Bay was removed from the list of required time/area closures that was considered in the 2011 DEIS. The following are the required time/area closures considered in the 2013 SDEIS: o Kaktovik and Cross Island o Barrow Canyon and the Western Beaufort Sea o Shelf Break of the Beaufort Sea o Hanna Shoal o Kasegaluk Lagoon o Ledyard Bay	This alternative remains the same as the one presented in the 2013 SDEIS. The only changes are the inclusion of one additional required time/area closure: Point Franklin to Barrow and the removal of Hanna Shoal from the list of required time/area closures that was considered in the 2011 DEIS and 2013 SDEIS. All other aspects of Alternative 5 are the same as Alternative 5 in the 2013 SDEIS with the exception of the changes made to the suite of required standard mitigation measures and additional mitigation measures based on public comments.

Alternative	2011 Draft EIS	2013 Supplemental Draft EIS	2016 FEIS
Alternative 6	There was no Alternative 6 in this version of the EIS.	Alternative 6 in this EIS is similar to Alternative 5 from the 2011 Draft EIS. The only change is the maximum amount of exploratory drilling activities that could potentially occur under this alternative increases from up to two in each sea, per year to up to four in each sea, per year.	Same as in the 2013 SDEIS with the exception of the changes made to the suite of required standard mitigation measures and additional mitigation measures based on public comments.

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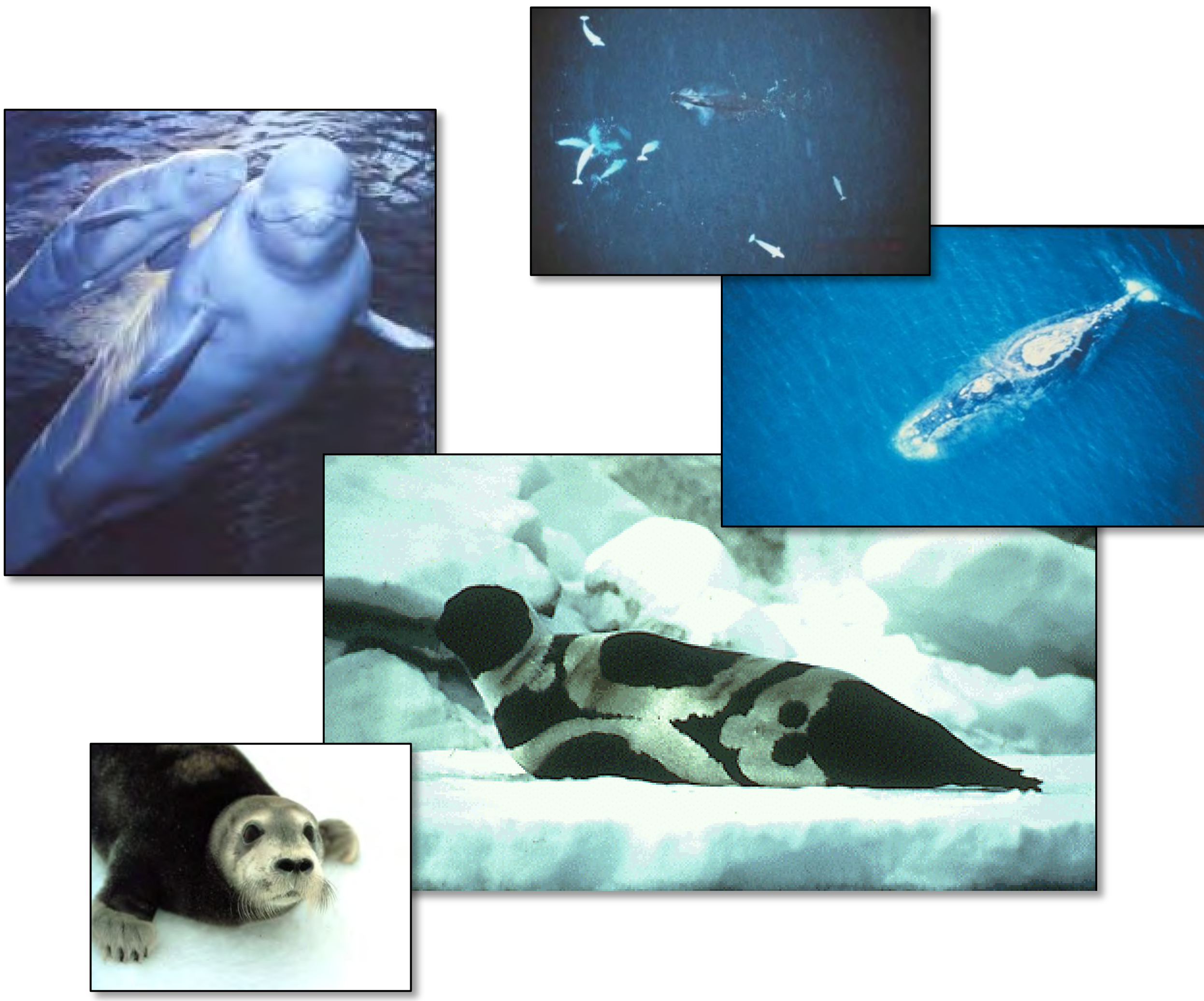
Final Environmental Impact Statement

Volume 2: Chapters 4-8



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somewhat larger, and the amount of time that multiple activities are co-occurring (and the number of activities that are co-occurring) either within or across the Beaufort and Chukchi seas is somewhat greater. For these reasons, these figures support the general suggestion that conducting the level of activity proposed for Alternative 4 could result in both impacts to more individual marine mammals, as well as impacts of a likely more intense nature (from the combined exposure to more activities in time and space), than conducting the level of activity proposed for Alternatives 2 and 3. However, the difference in the level of direct impacts between Alternative 4 and Alternative 3 is not expected to be as large as the difference between Alternative 3 and Alternative 2.

4.2.6 Estimating Take of Marine Mammals

4.2.6.1 Background

The MMPA prohibits the taking of marine mammals with certain exceptions, one of which is MMPA incidental take authorizations. Incidental take authorizations (ITA) allow for the take of small numbers of marine mammals if NMFS finds that the activity will have a negligible impact[2] on the affected marine mammal species and will not have an unmitigable adverse impact[3] on subsistence uses, and provided mitigation and monitoring requirements are set forth. Applicants for these authorizations are required by the MMPA implementing regulations to estimate (in advance) the number of individuals of each species that may be taken by their proposed activity [50 CFR 216.104 (a)(6)]. Take estimates are also necessary to inform the analyses that NMFS must conduct.

In order to help applicants with noise-producing activities understand when their activity might be expected to take a marine mammal (i.e., when an ITA would be needed) and to assist in the necessary quantification of likely takes, NMFS has established acoustic thresholds (discussed below). Acoustic thresholds identify received sound levels above which marine mammals would be expected to be taken (either by behavioral harassment or auditory injury), if exposed. In short, animals predicted to be exposed to levels at or above the acoustic threshold are predicted to be taken in the specified manner (i.e., by behavioral harassment or auditory injury).

The estimated number of animals that will be exposed at or above acoustic thresholds (and, therefore, predicted to be taken) is a valuable piece of both the “negligible impact” and “unmitigable adverse impact” analyses and directly informs whether the take numbers are “small,” however, it is only one piece of an effects analysis under the MMPA. The expected occurrence of a take or a particular *number* of estimated takes does not necessarily relate directly to the biological significance of the impacts, i.e., whether the takes will result in adverse impacts on the fitness or health of the individuals taken. The potential and likelihood of impacts on the health and fitness of individuals taken must be determined in consideration of the manner, context, duration, and intensity of those incidental takes.

For example, some takes (such as injuries or those with substantial negative energetic impacts) may have the potential to negatively affect reproductive success or survivorship, depending on the circumstances, while other takes may have no impact on the health or fitness of the affected individual. Typically, while many other factors come into consideration, exposures to higher levels of sound are generally expected to

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[2] Under the MMPA implementing regulations, a negligible impact is defined as an impact resulting from the specified activity that cannot be reasonably expected to, and is not reasonably likely to, adversely affect the species or stock through effects on annual rates of recruitment or survival (50 CFR § 216.103).

[3] An unmitigable adverse impact is defined as an impact resulting from the specified activity that is: 1) likely to reduce the availability of the species to a level insufficient for a harvest to meet subsistence needs by: causing marine mammals to abandon or avoid hunting areas; directly displacing subsistence users; or, placing physical barriers between the marine mammals and the subsistence users; AND 2) cannot be sufficiently mitigated by other measures to increase the availability of marine mammals to allow subsistence needs to be met.

result in more severe effects – and it is worth noting that, in the quantification of takes, due to the geometry of how sound spreads through water and NMFS historical "step" thresholds (where every exposure above a single level is estimated to be a take), the majority of the predicted number of takes would be expected to be on the lower end of levels associated with the effect the threshold illustrates, just above the threshold (i.e., less likely to be significant). If the analysis predicts that the activity is likely to adversely affect the reproductive success or survivorship of any individual marine mammals, then additional analysis must consider how the anticipated fitness effects to those individuals would likely affect the population (e.g., rates of recruitment and survival), in consideration of the species status. Additionally, the negligible impact analysis considers impacts on marine mammal habitat, such as impacts on prey species or the more difficult-to-quantify acoustic habitat impacts that can translate into chronic effects from longer-term exposure to increased sound levels.

Finally, the need to ensure "no unmitigable adverse impacts" to the availability of marine mammals for subsistence uses requires consideration of far more than just take numbers, both because activities can interfere with a hunt without ever affecting a marine mammal (e.g., by blocking access of hunters to marine mammals), and because it is possible for noise to affect marine mammals in a way that would make them more difficult to hunt without always rising to the level of a take (e.g., as traditional knowledge suggests, making them "skittish.")

4.2.6.2 Current Acoustic Thresholds

When assessing impacts to marine mammals from sound sources, NMFS has historically used the following acoustic thresholds for the types of sound sources analyzed in this EIS (meaning that take is predicted to occur, or assumed to have occurred, if animals are exposed at or above these levels). These thresholds have been applied to all marine mammal species under NMFS' jurisdiction.

- **Level A Harassment (potential injury) from all sound sources[4]: 180 and 190 dB re 1 µPa (rms) received level for cetaceans and pinnipeds, respectively**. These received levels represent the levels above which, in the view of a panel of bioacoustics specialists before TTS measurements for marine mammals became available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals (NMFS 1995, 2000).
- **Level B Harassment (behavioral harassment) from impulse sources (e.g., seismic airguns): 160 dB re 1 µPa (rms) received level for all species.** This sub-injurious threshold was based on measured avoidance responses observed in whales in the wild. Specifically, the 160 dB rms re: 1µPa threshold was derived from data for mother-calf pairs of migrating gray whales (Malme et al. 1983, 1984) and bowhead whales (Richardson et al. 1985; Richardson et al. 1986) responding when exposed to seismic airguns.
- **Level B Harassment (behavioral harassment) from continuous sources (e.g., drilling): 120 dB re 1 µPa (rms) received level for all species.** This threshold originates from research on baleen whales, specifically migrating gray whales (Malme et al.1984; predicted 50% probability of avoidance) and bowhead whales reacting when exposed to industrial (e.g., drilling and dredging) activities (non-impulsive sound source) (Richardson et al. 1990).

[4] Different Level A Harassment thresholds have been used by NMFS for other types of sound sources not analyzed in this EIS (e.g., explosives). Those thresholds are not listed here, as they are not relevant to the activity types analyzed in this document.

4.2.6.3 Revision of Acoustic Thresholds

Concurrently with the development of this EIS, NMFS undertook a rigorous process of revising and updating the thresholds for estimating onset of auditory injury (which NMFS considers the onset of Level A Harassment in the context of the MMPA) to incorporate newer science and utilize improved methods. In addition to ensuring that NMFS is using the appropriate acoustic thresholds in its decision-making processes, the development of these revised acoustic thresholds includes the creation of a single document/ reference that clearly articulates the thresholds, how they were scientifically derived, and how NMFS plans to apply them pursuant to the multiple NOAA authorities that address noise impacts (e.g., MMPA, ESA).

In the SDEIS, NMFS referenced and discussed the revision of these acoustic thresholds and how they could potentially affect our analyses, as well as our intent to include further discussion in the FEIS. At the time of publication of the SDEIS, NMFS believed that revisions to both auditory injury thresholds, as well as thresholds for acoustic behavioral harassment, would be complete by the time this EIS was finalized. However, because of the complexity involved in appropriately considering context, as well as multiple other technical and policy-related factors, NMFS does not anticipate the revisions to the acoustic thresholds for behavioral harassment will be completed for multiple years. Therefore, the analysis of behavioral effects in this FEIS maintains the current behavioral harassment thresholds (i.e., 160 dB for impulse sources like seismic and 120 dB for continuous sources like drilling), which NMFS determined represent the best available science and are used in combination with other qualitative factors that allow for robust assessment of the full effects of the analyzed actions. However, the revision of the auditory injury thresholds is final, and we consider those revised thresholds in this analysis.

The process for revising the auditory injury thresholds was separate from this NEPA process for Arctic Oil and Gas Exploration. The acoustic threshold revision process includes extensive internal (NOAA) review, multiple external peer reviews, and multiple public review periods. NMFS is aware of the time (sometimes multiple years) and resources that go into the preparation of environmental compliance documentation, and we acknowledge that there will be a transition period during which the new acoustic injury thresholds will be final and available, but many applicants will have already conducted extensive analyses using the historic thresholds. During this time, in some cases it will likely be necessary for NMFS to analyze the effects of activities for which we have take estimates based on historic thresholds, with an inclusion of qualitative consideration of the revised thresholds.

Government agencies must make decisions every day based on the best available science. NEPA requires agencies to conduct environmental impact analyses, some of which (as here) span multiple years during which science and policy related to the actions being considered are constantly evolving. As noted above, the process for revising the auditory injury thresholds included multiple peer reviews and public reviews. The last and final review of the revised auditory injury thresholds was a brief review by both the public and the peer reviewers focusing on a few specific technical changes in early 2016. The auditory injury thresholds considered in this EIS analysis are the new, revised final thresholds that were released by NOAA in July 2016 (see Appendix B). These guidelines include all of the input from the multiple peer-review and public input received throughout the process.

Below, we include a description of the final revised acoustic thresholds for auditory injury, along with a summary of the ways in which changes of the nature discussed might be expected to shape the analysis of effects contained elsewhere in the document (and informed by the current acoustic thresholds). Additionally, we include a brief discussion of NMFS' future plans to revise the behavioral harassment thresholds. As discussed in more detail above and below, acoustic thresholds are only one part of the analysis of marine mammal and subsistence impacts, and the analysis contained elsewhere in this document (informed by both the previous and revised final acoustic thresholds) creates a solid analytical foundation upon which considerations of acoustic threshold revisions can be layered for a fuller understanding of how the anticipated changes may inform future decision-making.

4.2.6.4 Auditory Injury Thresholds

As noted above, NMFS has finalized the process of revising its acoustic threshold levels for auditory injury (permanent threshold shift) via its 2016 Technical Guidance (NOAA 2016). Southall et al. (2007) identified dual criteria (using peak pressure sound pressure level [PK] and cumulative sound exposure level [SEL_{cum}]) for assessing PTS from multiple pulse sounds. Building upon those proposed levels, NMFS modified them using more recent data, which suggest: 1) that phocids should be separated from otariids when estimating TTS or PTS (because of their inner ear anatomy) and likely incur hearing impairment at lower received levels based on the data currently available (Kastak and Schusterman 1998; Hemilä et al. 2006; Mulsow et al. 2011), and; 2) that marine mammals are more likely to incur TTS and subsequent PTS within the frequency ranges of their best hearing sensitivity (Finneran and Schlundt 2010; Finneran and Jenkins 2012, Finneran 2015). An overview of the final revised auditory injury thresholds and weighting functions is included below. Tables including the final revised thresholds and figures depicting the associated marine mammal auditory weighting functions are included below and in Volume 3 of this FEIS. NMFS (2016), which was released to the public on March 16, 2016 for a last public comment and concurrent follow-up peer review, and describes the derivation of the revised thresholds in detail, is included here as Appendix B.

Table 4.2-4 Final revised auditory injury acoustic threshold levels

	PTS Onset Threshold Levels* (Received Level)	
Hearing Group	**Impulsive**	**Non-impulsive**
Low-Frequency (LF) Cetaceans	*Cell 1* $L_{pk,flat}$: 219 dB $L_{E,LF,24h}$: 183 dB	*Cell 2* $L_{E,LF,24h}$: 199 dB
Mid-Frequency (MF) Cetaceans	*Cell 3* $L_{pk,flat}$: 230 dB $L_{E,MF,24h}$: 185 dB	*Cell 4* $L_{E,MF,24h}$: 198 dB
High-Frequency (HF) Cetaceans	*Cell 5* $L_{pk,flat}$: 202 dB $L_{E,HF,24h}$: 155 dB	*Cell 6* $L_{E,HF,24h}$: 173 dB
Phocid Pinnipeds (PW) (Underwater)	*Cell 7* $L_{pk,flat}$: 218 dB $L_{E,PW,24h}$: 185 dB	*Cell 8* $L_{E,PW,24h}$: 201 dB
Otariid Pinnipeds (OW) (Underwater)	*Cell 9* $L_{pk,flat}$: 232 dB $L_{E,OW,24h}$: 203 dB	*Cell 10* $L_{E,OW,24h}$: 219 dB

* Dual metric acoustic threshold levels for impulsive sounds: Use whichever results in the largest effect distance (isopleth). If a non-impulsive sound has the potential of exceeding the peak sound pressure level thresholds associated with impulsive sounds, these thresholds should also be considered.

Note: Peak sound pressure (L_{pk}) has a reference value of 1 µPa, and cumulative sound exposure level (L_E) has a reference value of 1µPa^{2}s. In this table, thresholds are abbreviated to reflect American National Standards Institute standards (ANSI 2013). However, peak sound pressure is defined by ANSI as incorporating frequency weighting, which is not the intent for this Guidance. Hence, the subscript "flat" is being included to indicate peak sound pressure should be flat weighted or unweighted within the functional hearing range. The subscript associated with cumulative sound exposure level thresholds indicates the designated marine mammal auditory weighting function (LF, MF, and HF cetaceans, and PW and OW pinnipeds) and that the recommended accumulation period is 24 hours. The cumulative sound exposure level thresholds could be exceeded in multitude of ways (i.e., varying exposure levels and durations, duty cycle). It is valuable for action proponents, if possible, to indicate under what conditions these acoustic threshold levels will be exceeded.

Source: NMFS 2016

When considering how the final revised acoustic thresholds for auditory injury outlined above might compare to the current 180/190-dB rms thresholds, it is important to note three important differences in what the two sets of thresholds (former and revised) represent. First, dual criteria are utilized, meaning that whichever is exceeded first is the one that should be used for assessing injury for impulsive sources (in almost all cases, the SEL_{cum} metric will be exceeded first). Second, the thresholds outlined above use the SEL_{cum} metric (which allows for the consideration of how the sound accumulates over time), not the SPL rms metric of the current thresholds (which does not directly take into account the duration of exposure). (Note that the revised PK metric also does not account for accumulation.) This means, for

example, that one 100-ms pulse with a received SPL rms level of 161 dB would only have an SEL of 151 dB. However, multiple pulses must be taken into consideration, and, if a receiver were in a position to receive 10 of those same pulses within that same distance, the SEL_{cum} would accumulate up to 161 dB (e.g., SEL_{cum} equals SPL rms levels when the total duration of exposure to the same level is 1 second). Last, the SEL_{cum} thresholds outlined above take into account the frequency range of highest sensitivity for each functional hearing group and are intended to be used in conjunction with frequency weighting functions that are depicted above and outlined in more detail by NMFS (2016; see Appendix B). In short, applying frequency weighting functions considers sound produced by the source in conjunction with the functional hearing group-specific and frequency-specific filter and for any part of the signal that is not in the area of highest sensitivity for that functional hearing group, i.e., more energy is needed to reach the threshold (e.g., range to isopleth decreases).

Because our understanding of marine mammal hearing has advanced greatly, these final revised auditory injury thresholds are notably more complex to apply (primarily in how they consider taxa-specific auditory weighting functions and exposure duration) and have the potential to be challenging for applicants without the benefit of more sophisticated modeling capabilities. Therefore, NMFS has provided simplified methods (i.e., less sophisticated models) to incorporate weighting functions and exposure duration that ***may*** be used if applicants do not have access to models that cannot account for these factors. This simple method generates a "safe distance" (the distance from the source beyond which a threshold for that metric is not exceeded) and accounts for several factors, including source level, interpulse interval or duty cycle, and velocity of the source, and is independent of exposure duration. Appendix B describes this simplified method in more detail and outlines the simplifying assumptions. This method is considered conservative because of some of the inherent assumptions and is expected to result in a higher take estimate than if more sophisticated modeling (which can be carefully refined to the specific parameters of a given survey/environment) is used.

Appendix G of the FEIS depicts representative 120, 160, 180, and 190-dB isopleths (the latter two representing the distances within which cetaceans and pinnipeds, respectively, could potentially incur auditory injury in the form of PTS based on historic thresholds) from past seismic surveys. As noted previously, in the past, NMFS did not typically authorize Level A take because we assumed marine mammal avoidance of loud sounds and effective mitigation would likely result in avoidance of auditory injury. Using the final revised acoustic thresholds and the simple method referenced above, NMFS calculated the "safe distances" for seismic surveys and a simplified 24-hr accumulation for drilling, which (when the simple method is used) would likely be used in lieu of the historic 180 and 190-dB isopleths to calculate take. By comparing these simple method calculations with the historic 180 and 190-dB isopleths, we can get a sense of the differences between predicted injury using the historic auditory injury thresholds versus using the final revised acoustic thresholds.

Using the simple method (with final revised thresholds and weighting functions) and some basic generalizations (based on data) about larger array seismic surveys (source level of 235 dB RMS SPL, source velocity of 2.315 m/s, 0.01 duty cycle), we calculated the following safe distances for the SEL metric: 2,119 m for low frequency cetaceans, 2 m for mid-frequency cetaceans, 240 m for high frequency cetaceans, 350 m for phocids, and 7 m for otariids. The new acoustic guidance provide dual metrics (SEL and SPL peak) and instruct users to use the more conservative of the two (i.e., the one that would result in the larger isopleth or greater take estimates). In this example, using the SEL metric produces the larger isopleths for all but mid-frequency cetaceans, for which the SPL peak isopleth would be about 6 m, assuming that the SPL peak source level is about 10 dB above the SPL rms level and assuming a spreading coeeficient of 20logR. These safe distances are very much within the realm of the 180 and 190-dB isopleths that have been modeled or measured in past surveys (in fact, they are substantively smaller for mid and high frequency cetaceans and otariids), suggesting that the revisions in the auditory injury thresholds do not change our analysis of impacts notably, and further suggesting that traditionally applied 180 and 190-dB mitigation zones likely provide a similar degree of protection as previously assumed.

Using the simple method (with final revised thresholds and weighting functions) and some basic generalizations (based on data) about drilling activities (source level of 187 dB RMS SPL, activity duration of 24 hours, and transmission loss of 15 logR) the following safe distances were calculated: 309 m for low frequency cetaceans, 17 m for mid-frequency cetaceans, 271 m for high frequency cetaceans, 166 m for phocids, and 12 m for otariids. Measured 180 and 190-dB RMS SPL isopleths for drilling are typically much smaller (on the order of 10 m or less) and injury has not typically been anticipated or authorized. Prior assessments of the unlikelihood of injury would likely not change given the small area encompassed by the safe distance (and resulting small take estimates, if projected) and the expectation that many marine mammals will avoid sounds at these levels. The safe distances above assume that animals remain closer than that to the noise source for a full 24 hours to exceed the exposure threshold, which is quite unlikely. However, the potential for injury should not be entirely ruled out, especially in situations where there is reason to believe that marine mammals need to be in the immediate area for extended periods of time, and some small number may occasionally be authorized.

4.2.6.5 Behavioral Harassment Thresholds

As noted above, NMFS is planning to revise the acoustic thresholds for behavioral harassment for all activities. When the DEIS and SDEIS were published, we believed that this process would be complete in time to inform the FEIS, however, we have since realized that that the revision of the behavioral harassment thresholds will take at least an additional couple of years to complete, given some of the known technical and policy challenges associated with such a revision. Given this delay, and in consideration of both the evolving science and the upcoming process, which will include extensive expert and public input and could result in recommended methods that are currently unforeseen, the analysis contained in this FEIS utilizes NMFS' current behavioral harassment thresholds for estimating take. Nonetheless, we outline below some of the limitations of the current thresholds and highlight opportunities to qualitatively consider the most up-to-date information.

The current acoustic threshold for behavioral harassment from impulsive sounds, a 160-dB rms step function, predicts that all animals exposed to levels above 160 dB would be taken, and that no animals exposed to levels below 160 dB would be taken. Both data and logic suggest that this method may oversimplify the relationship between sound exposure and behavioral harassment, and there are other methods available that could better characterize this relationship, given the available data, while also incorporating consideration of variability in individual responses to sound. Dose-response-type curves, or risk functions, when supported by data and with an appropriate cut-off, can be used to more fully describe how exposures to different received levels can result in different outcomes (e.g., number of animals responding in a certain way, probability of individual responses). For example, given a specifically defined response, a risk function could describe how a higher percentage of animals exposed to higher received levels might demonstrate that response, while a lower percentage of animals exposed to lower received levels might demonstrate that response (see example used for Navy mid-frequency sources below). NMFS' preliminarily plans include exploring the use of dose-response or risk function-like curves to characterize the relationship between received sound level and behavioral responses. Further, while other metrics have been explored, based on the available data NMFS' believes that dB rms (the metrics used in the current acoustic thresholds) is still the most appropriate metric to characterize the relationship between received level and behavioral response.

Additionally, as has become increasingly evident and more highlighted in publications (Ellison et al., 2011), the context of an exposure of marine mammals to sound (e.g., the behavioral state of the animal, whether a sound source is approaching and how fast) can affect both how an animal initially responds to a sound and the ultimate impacts of the sound exposure on that individual. NMFS is also exploring additional methods of augmenting the use of a dose-response-like curve to address contextual factors beyond received level (such as distance from the sound or behavioral state of the animal), as well as the more chronic effects of sound sources operated over longer periods of time.

In the future, based on the limited data available, NMFS is considering exploring having different basic acoustic thresholds for mysticetes, odontocetes, and pinnipeds, with the recognition that sometimes there may be sufficient data to suggest that a species within one of those groups is "sensitive" and should have different (lower) acoustic threshold. Because data indicate that not all mysticetes exposed to received levels of 160 dB or above would be expected to be taken (Miller 2005, Malme et al. 1983, 1984, 1985), a dose-response approach for mysticetes, if explored, would likely result in estimates that show fewer takes resulting from exposures to received levels above 160 dB (than when the current step function is used). Alternately, there are also data showing that some portion of mysticetes (including, and perhaps especially, bowheads) exposed to seismic signals at received levels below 160 dB, and potentially down to around 120 dB, may sometimes respond in a manner that NMFS would categorize as a Level B behavioral take, especially in certain contexts, such as within a migratory corridor or if the activity were expected to be continuous over multiple days (Di Iorio and Clark 2009, Richardson et al. 1985/1986, Richardson et al. 1999). A dose-response-like approach incorporating these data, if explored, would likely result in some number of animals exposed at levels below 160 dB being predicted to be taken. However, while considering these approaches through the appropriate process, we believe that the 160-dB is still the best generalized method for predicting when level B harassment occurs.

Fewer data exist showing how odontocetes and pinnipeds (as compared to mysticietes) behaviorally respond to seismic airguns and similar sources. However, what data are available suggest that some percentage of odonotcetes exposed to received levels above 160dB would not be taken and that some percentage exposed to levels below 160 dB may respond in a manner that NMFS would consider Level B harassment (Miller et al. 2005). Alternately, data suggest that not all pinnipeds will be taken at received levels of 160 dB (or higher), and there are no data (with measured received levels) indicating how they would respond to levels below 160 or 165 dB.

In consideration of the acoustic threshold revisions, NMFS qualitatively considers how changes of the nature described above could potentially shape our further analyses of the alternatives in this FEIS. As described above, much of the impact analysis occurs subsequent and in addition to the initial estimate of the number of exposures that are predicted to result in a take. This additional analysis determines whether the anticipated exposures with the potential to injure or disturb marine mammals (counted as takes) would be likely to affect the health or fitness of any individuals (in a manner that would affect survivorship or reproductive success), whether altered health or fitness of the expected number of individuals would adversely affect rates of recruitment or survival, and whether any of the expected effects on individuals would have an unmitigable adverse impact on subsistence uses.

As discussed above, the quantification of anticipated takes is only part of the larger marine mammal impact analysis and is separate from the analysis of the severity of any single one of those takes, which must consider the biological and operational context in which those takes occur. Additionally, the analysis of the potential health and fitness impacts of the expected take, or the population level impacts, includes consideration of the life history of the affected species, their behavioral patterns and distribution within the action area, the duration, season, geographic scope, and operational parameters of the expected activities, along with the potential implementation of multiple mitigation measures intended to minimize the intensity of the effects – and these analyses are not expected to change notably based solely on any anticipated future modification of the behavioral harassment threshold.

Separately, any revisions to the acoustic thresholds also result in changes to the distances from sound sources within which we quantify impacts. NMFS has previously qualitatively acknowledged our concerns regarding the more chronic, longer-term effects of increasing noise levels (at levels below 160 dB) in potentially interfering with marine mammal's ability to detect and interpret important environmental cues (especially for low frequency specialists and low frequency sounds). For example, we outlined the 120-dB isopleths around seismic airgun operations in the original DEIS (even though the current acoustic threshold for behavioral harassment is 160 dB) to give a sense of the geographic scope of these chronic noise concerns. In response to public comments requesting NMFS better address the effects

of more chronic and aggregate noise exposure, NMFS has conducted a novel first-order chronic and cumulative analysis, the preliminary results of which have been reported in Section 4.5.2.4.9 and considered in the FEIS analysis.

4.2.6.6 Overview of Take Estimates

Tables 4.2-5, 4.2-6, and 4.2-7 contain a representative summary of takes that were predicted to occur in the Beaufort and Chukchi seas based on previously issued IHAs for the different types of activities analyzed in this EIS.

In 2015, NMFS modified the way we calculate take in certain situations and some activities to better account for the duration of the activities, which resulted in take numbers that were sometimes several times higher than those calculated in previous years. While these estimates better account for duration, it is also important to note that the numbers generated with this newer method represent the number of *instances* of take, not the number of *individuals* taken. The higher take estimates generated using the newer methods are expected to be overestimates of the number of individuals taken to differing degrees because of the fact that depending on several factors (activity type, behavior, life history, etc.) individuals are likely taken more than one time on multiple days across the duration of the action. Further, because the takes from each activity type indicated below are simply added together, the totals generated for each alternative do not take into consideration the fact that an animal may be taken by two or more different activities (i.e., just adding activity takes may further overestimate the number of individuals). For example to illustrate both of these points, a bowhead may remain in an area for a couple days feeding and therefore be taken by a stationary drilling activity a couple of times (reflected as two takes in activity estimate), and then move away continuing on its migration and swim through the ensonified zone of a couple of seismic surveys and be taken two more times. In such a scenario, four of the takes represented in the take estimate for a total alternative would actually represent only one individual. Alternately, animals that remain in the general area of these activities all year round or for a season may be taken many more times each. Therefore, although newer methods may increase the estimated take numbers in applications by several times over those reflected in the tables below, because of the reasons above, we determined that the alternative totals below still generally represent the *numbers of individuals* that may be taken by the combined activities. However, in acknowledgement of the generalized nature of these take estimates and the new methods mentioned above, we will consider the possibility that the number of individuals could be twice as high as those reflected in the tables below when we address magnitude or intensity in the impact criteria for behavioral disturbance.

Using the methods described in the previous paragraph, Table 4.2-5 indicates that between 3,460 and 6,920 bowheads might be behaviorally harassed as they travel through the Beaufort Sea under Alternative 2. Fleishman et al. (2016) modeled 80% of the bowhead population (11,566) moving through the Beaufort Sea in a 47-day period and their sound exposure given the modeled sound field of two production islands, one offshore and one nearshore vessel towing a barge, and two offshore and three nearshore seismic survey operations. In the modeled scenario, given a 0.6 probability of modeled aversion to seismic at 160 dB SPL (which seems reasonable), about 22% of the modeled population (2,544 individuals) was exposed to levels of 160 dB or above at some time during their trip through the Beaufort, though only about 1% of the population was exposed to levels above 170 dB. If this number is proportionally corrected for the current minimum population estimate (16,091) passing through the same fields, the exposures above 160 dB SPL would be 3,540. Alternative 2 assumes four 2D/3D seismic surveys, three site clearance, one on-ice survey, and one exploratory drilling program in the Beaufort Sea. Given the general similarity between the levels of activity contemplated in Alternative 2 and the levels of activity contemplated in Ellison et al. (2016; acknowledging that Alternative 2 levels are somewhat higher), and the fact that cumulative exposure to multiple sources is not strictly additive, the exposures modeled in Ellison et al. (2016) generally do not seem to be out of line with the exposures above 160 dB estimated here for Alternative 2.

Separately, note that the estimates presented below all represent Level B behavioral harassment takes and assume no injury (or mortality) based on previous analyses using historical Level A harassment thresholds and assumptions about avoidance and mitigation. As described above, future analyses and calculations utilizing the revised auditory impact thresholds will likely not result in much of a change to predicted numbers, but it is probably not appropriate to rule out the chance of PTS completely, so there may be cases in the future in which, based on the project-specific analysis conducted, NMFS authorizes a small number of Level A harassment takes. However, if so, it would not change the numbers in the table below, as those Level A harassment takes would come from the pool of takes that would otherwise have been estimated as Level B harassment. We also emphasize here that not all takes are biologically significant. Additional contextual analysis is needed and typically only some portion (depending on the circumstances and context of the exposures) of any estimated takes have the potential or likelihood of affecting animal fitness.

Table 4.2-5 Examples of estimated take for different types of oil and gas exploration activities in the Beaufort Sea using the current behavioral acoustic thresholds, followed by estimated takes if those examples are used to total maximum activity levels for each alternative.

BEAUFORT	Bowhead Whale	Beluga Whale	Gray Whale	Minke Whale	Humpback Whale	Harbor Porpoise	Ringed Seal	Bearded Seal	Spotted Seal	Ribbon Seal
OBC or OBN Seismic Survey using an 880 in^3 array	20	15	0	0	0	0	225	30	15	0
3D Seismic Survey using a 3147 in^3 array	400	210	250	0	0	0	7300	375	20	0
Site Clearance and High Resolution Shallow Hazards Survey using a 40 in^3 airgun	300	10	5	0	0	0	140	10	5	0
On-ice Seismic Survey	0	0	0	0	0	0	500	5	0	0
In-ice 2D Seismic Survey	240	4900	20	18	18	18	39,200	70	17	17
Exploratory Drilling Program with a drillship	1500	20	10	0	0	15	440	22	5	2
ALTERNATIVE 2 Total - Maximum levels of all Beaufort activities combined	**3460**	**5385**	**545**	**18**	**18**	**33**	**55385**	**907**	**92**	**19**
ALTERNATIVE 3 Total - Maximum levels of all Beaufort activities combined	**5980**	**5650**	**815**	**18**	**18**	**48**	**63630**	**1354**	**142**	**21**
ALTERNATIVE 4 Total - Maximum levels of all Beaufort activities combined	**8980**	**5690**	**835**	**18**	**18**	**78**	**64510**	**1398**	**152**	**25**

Table 4.2-6 Examples of estimated take for different types of oil and gas exploration activities in the Chukchi Sea using the current behavioral acoustic thresholds, followed by estimated takes if those examples are used to total maximum activity levels for each alternative.

CHUKCHI	Bowhead Whale	Beluga Whale	Gray Whale	Minke Whale	Humpback Whale	Fin Whale	Killer Whale	Harbor Porpoise	Ringed Seal	Bearded Seal	Spotted Seal	Ribbon Seal
3D Seismic Survey using a 3000 in^3 array	150	190	145	5	5	5	5	20	6,500	215	130	10
Site Clearance and High Resolution Shallow Hazards Survey using a 40 in^3 array	5	10	20	2	2	2	5	7	700	30	7	2
In-ice 2D Seismic Survey	40	50	5	5	5	0	0	5	21,300	20	5	5
Exploratory Drilling Program with a drillship	80	15	50	15	15	15	15	15	815	35	20	15
Exploratory Drilling Program with a jack-up rig	70	10	35	5	5	5	20	10	340	160	160	15
ALTERNATIVE 2 Total - Maximum levels of all Chukchi activities combined	**435**	**475**	**405**	**36**	**36**	**31**	**40**	**81**	**37215**	**575**	**306**	**46**
ALTERNATIVE 3 Total - Maximum levels of all Chukchi activities combined	**825**	**890**	**785**	**65**	**65**	**60**	**75**	**150**	**52430**	**1100**	**600**	**85**
ALTERNATIVE 4 Total - Maximum levels of all Chukchi activities combined	**985**	**920**	**885**	**95**	**95**	**90**	**105**	**180**	**54060**	**1170**	**640**	**115**

Table 4.2-7 Using the examples provided above, estimated takes for total maximum activity levels in both the Beaufort and Chukchi seas combined for each alternative*.

BEAUFORT/CHUKCHI COMBINED	Bowhead Whale	Beluga Whale	Gray Whale	Minke Whale	Humpback Whale	Fin Whale	Killer Whale	Harbor Porpoise	Ringed Seal	Bearded Seal	Spotted Seal	Ribbon Seal
ALTERNATIVE 2 Total - Maximum levels of all activities combined	3895	5860	950	54	54	31	40	81	92,600	1,482	398	65
ALTERNATIVE 3 Total - Maximum levels of all activities combined	6805	6540	1600	83	83	60	75	150	116,060	2,454	742	106
ALTERNATIVE 4 Total - Maximum levels of all activities combined	9965	6610	1720	113	113	90	105	180	118,570	2,568	792	140

* Note, for the reasons described above in Section 4.2.6.6, for the purposes of evaluating the magnitude or intensity for the behavioral disturbance impact criteria, NMFS is considering values of twice those indicated in this table.

4.5.1.4 Acoustics

The term acoustics for purposes of this EIS refers to the state of ensonification of the environments of the EIS project area by anthropogenic noise resulting from activities of the alternatives. The acoustic environment is an important habitat component for multiple species. For example, sound is critical to marine mammals for communication, prey and predator detection, and for detecting and interpreting other important environmental clues (e.g., navigation). The presence of increased sound levels from anthropogenic activity and consequent exposures of marine wildlife to these conditions could potentially cause effects. In addition, the acoustic environment influences the success of subsistence uses through disturbance and behavior modification of marine mammals and other subsistence resources, and potentially impeding subsistence harvest activities and use of the environment. This section considers levels of ensonification (intensity), duration and spatial extent of anthropogenic noise produced by Alternative 2 to inform the wildlife and subsistence effects assessments elsewhere in this EIS. Alternative 2 is the first alternative that introduces anthropogenic noise sources associated with oil and gas exploration. The acoustic characteristics of these sources are compiled and discussed in this section specifically for Alternative 2 but the same sources are used in other alternatives and the information presented here is also relevant for those.

The evaluations of acoustics effects in this section consider three criteria: intensity, duration, and extent, as defined in Table 4.5-8 below. The criteria are based on sound levels that have been associated with possible disturbance of marine mammals, although specific impacts are not considered here (see section 4.2.6). Intensity considers the magnitude of the broadband acoustic source levels associated with the activity. Duration considers the time period over which sound sources operate. Extent considers the spatial area over which sound levels exceed the lowest marine mammal disturbance level relative to the Beaufort and Chukchi seas; the impact category of context is not applicable to acoustics, as it is not a resource that can be classified as common, important, or unique (although context in a more general sense is critical to an assessment of acoustic impacts and is therefore discussed in relation to its importance to certain biological resources in those individual sections).

Table 4.5-8 Impact Criteria for Acoustics

Impact Category	Intensity Type	Definition
Intensity (Magnitude)	Low	Broadband acoustic source levels from anthropogenic sources are below 160 dB re 1 uPa @ 1 m (either continuous SPL or 90% rms SPL for impulsive sources).
	Medium	Broadband acoustic source levels from anthropogenic sources reach or exceed 160 and are below 200 dB re 1 µPa @ 1 m.
	High	Broadband acoustic source levels from anthropogenic sources reach or exceed 200 dB re 1 uPa @ 1 m.
Duration	Temporary	Acoustic levels are modified for days to one month.
	Interim	Acoustic levels are modified for 1 to 6 months (an entire project season).
	Long-term	Acoustic levels are increased for more than 6 months in a given year or for multiple months that recur over multiple successive years.
Geographic Extent	Local	Anthropogenic noise levels are increased above 120 dB re 1 uPa over less than 10% of the EIS project areas.
	Regional	Anthropogenic noise levels exceed 120 dB re 1 uPa over at least 10% and less than 50% of the EIS project areas.
	State-wide	Anthropogenic noise levels exceed 120 dB re 1 uPa over 50% or more of the EIS project area.

Alternative 2 includes exploration activities that would likely require an ITA for possible harassment of marine mammals from noise produced by seismic survey sources, drill rigs and vessels. Other than the No Action Alternative, Alternative 2 contemplates the lowest level of activity.

Noise sources included in Alternative 2 include deep-penetration seismic airgun arrays, seismic survey vessels, including in-ice seismic vessels for winter programs, small airgun arrays for site clearance and high resolution shallow hazards surveys or for use during VSP surveys in conjunction with exploration drilling activities, vibroseis systems for on-ice surveys, and drilling rigs. With the exception of exploratory drilling rigs, all of the source types have operated in the EIS project area environments for commercial oil and gas exploration projects between 2006 and 2010. Most of these projects operated under IHAs that required acoustic measurements of underwater noise sources, and the results are cataloged in a series of monitoring reports submitted to NMFS (see references in Table 4.5-8). The reports dating back to 2006 are publicly available on NMFS' ITA website: http://www.nmfs.noaa.gov/pr/permits/incidental.htm.

Table 4.5-9 lists the specific programs conducted in the EIS project area and the sources included in the reported acoustic measurements that are relevant to understanding sound levels produced by airgun arrays and vessels as included in activities under the alternatives.

Table 4.5-9 O&G Exploration Projects in the EIS Project Area, 2006- 2015, that have reported measurements of sound levels produced by their activities

Project Operator and Year	Primary Survey Type	Location	Water Depths (m)	Airgun Array	Survey Vessel	Support Vessel	Sidescan/Multibeam	Sub-bottom Profiler	Spark/Boom/Pulse	Drilling	Reference
Shell Offshore Inc. 2006	3D 3D, SH	Chukchi, Beaufort	40 40-50	X X	X X	X X			 X		Blackwell 2007
GX Technology 2006	2D	Chukchi	30-3,800	X							Austin & Laurinolli 2007
ConocoPhillips Alaska 2006	3D	Chukchi	<50	X	X						MacGillivray & Hannay 2008
Shell Offshore Inc. 2007	3D, SH	Chukchi, Beaufort	40+	X	X	X		X	X		Hannay et al. 2008
Eni and PGS 2008	OBC	Beaufort	2-14	X	X	X					Warner et al. 2008
BP Alaska 2008	OBC	Beaufort	0.3-9.1	X	X	X					Aerts et al. 2008
ConocoPhillips Alaska 2008	SH	Chukchi	32		X				X		Turner and Trivers 2008
Shell Offshore Inc. 2008	3D, SH	Chukchi, Beaufort	19-44	X	X	X		X	X		Hannay et al. 2009
Shell Offshore Inc. 2009	SH	Chukchi	48, 41	X	X			X			Warner et al. 2010
Statoil 2010	3D	Chukchi	38-43	X							O'Neill et al. 2010
Shell Offshore Inc. 2010	SH,GT	Chukchi, Beaufort	46-51 15-38	 X	X X		X X	X X			Chorney et al. 2011

Project Operator and Year	Primary Survey Type	Location	Water Depths (m)	Airgun Array	Survey Vessel	Support Vessel	Sidescan/Multibeam	Sub-bottom Profiler	Spark/Boom/Pulse	Drilling	Reference
Statoil 2011	SH,GT, GC	Chukchi	37	X	X	X	X	X			Warner and McCrodan, 2012
BP 2012	OBC	Beaufort	1.8-18	X	X						McPherson and Warner, 2012
ION 2012	2D	Beaufort	50-1016	X	X						Wladichuk et al. 2013
Shell 2012	DR	Beaufort				X				X	Austin et al. 2013
Shell 2012	DR	Chukchi				X				X	Austin et al. 2013
Shell 2013	SH, GT	Chukchi	42-48	X	X	X	X	X			Reider et al. 2013
TGS 2013	2D	Chukchi	41-48	X	X	X					Austin and Baily 2013
SAE 2014	OBC	Beaufort	4.0-7.9	X							Heath et al. 2014
Shell 2015	Drilling	Chukchi	46							X	Austin and Li 2016

Notes:

2D = 2-Dimensional seismic survey using airgun array sources
3D = 3-Dimensional seismic survey using airgun array sources
OBC = Ocean Bottom Cable or Ocean Bottom Sensor survey using airgun array sources
SH = Site Clearance and high resolution shallow hazards surveys using small airgun arrays, sparkers or boomers or bubble pulsers.
GT = Geotechnical survey using sidescan, multibeam, single beam sonars
GC = Geotechnical Coring
DR = Drilling using drillship or drill rig

4.5.1.4.1 Acoustic Propagation Environments

The Alternative 2 noise sources generate acoustic footprints that depend on the source type and location of operation. For this discussion, the overall EIS project area is divided into three primary acoustic environments introduced in Section 3.1.4.1. These environments are the Chukchi shelf, the Beaufort shelf, and Beaufort coastal area. Though the sediment type and water column features may vary across these environments, the primary distinguishing factor for influencing sound propagation in each environment is water depth. The EIS project area on the Chukchi Shelf is comprised of spatially-uniform water depths between approximately 25 m (82 ft.) and 50 m (164 ft.) in the areas of oil and gas activities. Bottom relief over the extent of individual seismic or site clearance survey areas is generally small, typically within 10 percent of the nominal location depth, but spatially-extended 2D surveys can cover larger depth intervals. The Beaufort shelf areas have a larger depth range, from approximately 15 m (50 ft.) to a few hundred meters near the shelf edge; however, most recent exploration activity has occurred in less than 35 m (115 ft.) water depth. The lower depth range limit of 15 m (50 ft.) is due mainly to difficulties towing seismic streamers in shallower water. Surveys in shallower water are performed using OBC/OBN systems with hydrophones deployed on the seabed. OBC surveys were performed by Eni/PGS and BP in 2008 inside the barrier islands of the Beaufort Sea, in water depths less than 5 m (16 ft.), to a few kilometers outside the islands in water depths to approximately 15 m (50 ft.).

4.5.1.4.2 Relevant Acoustic Thresholds

Acoustic footprints will be considered in terms of areal extents and source-receiver distances to specific noise thresholds that are pertinent for assessing marine mammal acoustic impacts. NMFS historically

considered thresholds of 190 and 180 dB re 1 µPa (rms) to be representative of the levels below which we can be confident that PTS (or auditory injury) will not occur, based on TTS data in pinnipeds and cetaceans respectively. Thresholds for marine mammal disturbance are 120 dB and 160 dB re 1 µPa for continuous and pulsed noises, respectively. However, as discussed in Section 4.2.6.4 of this EIS, NMFS has revised its acoustic thresholds for auditory injury. NMFS notes that marine mammals may respond to pulsed noise at levels below 160 dB re 1 µPa (potentially down to 120 dB) in a manner with the potential to impact subsistence uses of those animals, and, therefore, distances to the 120 dB re 1 µPa isopleths are typically identified for both continuous and pulsed sources. Richardson (1995) noted bowhead deflections at 35 km (21 mi) distance from a seismic survey airgun array source in the Alaskan Beaufort Sea, and estimated the corresponding exposure SPL between 125 and 133 dB re 1 µPa. Additionally, as noted earlier (Section 4.2.6), other studies also suggest that some portion of mysticetes may respond to seismic sources at received levels lower than 160 dB (potentially down to 120 dB) in a manner that NMFS would consider harassment, and therefore, we are currently considering revisions to the acoustic thresholds for behavioral harassment. Therefore, acoustic information will be presented pertaining to the occurrence of sound levels at threshold values of 190 dB, 180 dB, 160 dB and 120 dB re 1 µPa.

4.5.1.4.3 Acoustic Footprints of Airgun Sources

Airgun array sources generate impulsive sound with source levels typically exceeding 200 dB re 1 µPa @ 1m. The SSV measurements for the oil and gas programs listed in Table 4.5-8 have determined the distances at which certain sound level isopleths from airgun sources are reached. The common approach to determine threshold distances has been to fit smooth curves through broadband rms SPL measurements and then to select the distances at which the curves cross the thresholds (Warner et al. 2008). Conservative estimates of the distances are obtained by shifting the best-fit curves upward in level so they exceed 90 percent of the measurement data values. The distances determined from the shifted curves are referred to as 90th percentile distances. Most of the measurements of airgun array sources have sampled sound levels in both the endfire direction (parallel to airgun array tow direction) and broadside direction (perpendicular to tow direction) to quantify direction-dependent sound emissions. Appendix G provides a summary of the airgun array measurements that have been performed for the programs listed in Table 4.5-9. Measured distances for sound, including seismic survey sound, change depending upon ambient conditions (e.g., wind, waves, salinity, temperature). Therefore, Appendix G provides a snapshot of one set of measurements taken at these sites rather than a static threshold.

The results in Appendix G exhibit variability of the measured levels, even when considering similar sources in the same primary acoustic environment. This can arise due to differences in the source geometry such as the layout of airguns in an array and the tow depth. The results are also dependent on the seafloor sediment types and the structure of the ocean sound speed profile, both factors that influence sound propagation. At present, there is not sufficient geoacoustic information available to quantify these differences and allow the primary acoustic environments to be further subdivided. Instead the measurements have been averaged to provide representative propagation ranges for each environment by size of source.

Representative distances to sound level thresholds of 190, 180, 160 and 120 dB re 1 µPa (rms) for airgun sources were obtained by averaging Appendix G results for offshore and coastal surveys, and are presented in Table 4.5-11. The averages are based on the 90th percentile measured distances and the maxima of broadside and endfire measurements where both directions are sampled. These distances were used to assess the direct and indirect acoustic effects zones from airgun sources for each action alternative.

Table 4.5-11 Average distances to sound level thresholds from measurements listed in Appendix G for several airgun survey systems.

The averages are based on 90th percentile distances, where available, and the maxima of broadside and endfire measurements are used where both directions were sampled.

Array Volume (in^3)	Average distance (m) and standard deviation to sound levels (dB re 1 µPa; 90% rms SPL) based on 90th percentile fit			
	190	180	160	120
Chukchi Sea Shelf, 25 to 50 m depth				
10	13 (6)	44 (10)	506 (191)	18380 (6801)
20	26 (8)	76 (10)	710 (177)	20333 (4643)
40	<10 (-)	76 (-)	1360 (-)	41100 (-)
60	37 (10)	127 (26)	1320 (397)	27200 (3544)
105	10 (3)	56 (13)	1550 (50)	43000 (17000)
1049	62 (-)	179 (-)	1449 (-)	30988 (-)
~3200	420 (-)	1350 (-)	3240 (-)	61400 (-)
Beaufort Sea Shelf, ≥15 m depth				
10	21 (23)	53 (48)	401 (135)	12710 (3340)
20	17 (17)	54 (41)	729 (199)	17475 (5197)
30	8 (5)	30 (22)	1180 (188)	24600 (490)
40	24 (-)	158 (-)	1602 (-)	9221 (-)
70	24 (1)	84 (10)	1051 (310)	27670 (24330)
280	89 (-)	250 (-)	1750 (-)	22220 (-)
320	360 (-)	1134 (-)	4265 (-)	13313 (-)
640	516 (-)	1386 (-)	4616 (-)	14163 (-)
3147	889 (32)	2573 (328)	11453 (1953)	74813 (-)
4380	341 (54)	1770 (520)	12480 (6220)	96450 (34550)
Beaufort Coastal, <15 m depth				
10	54 (-)	188 (-)	1049 (-)	n/a
20	52 (31)	139 (53)	833 (175)	6525 (4275)
40	147 (9)	263 (30)	1016 (83)	3242 (-)
320	260 (-)	472 (-)	1545 (-)	16598 (-)
320	195 (-)	635 (-)	1818 (-)	n/a
880	225 (45)	485 (90)	2225 (1021)	14500 (7015)

A dash (-) signifies that only one data point was available and standard deviation could not be calculated.

4.5.1.4.4 Acoustic Footprints of Non-Airgun Sources

The non-airgun sources of Alternative 2 include seismic vessels, support vessels, drill rigs (drillships and jack-up rigs) and on-ice surveys using vibroseis. Site clearance surveys also employ high-resolution acoustic sources including multibeam and sidescan sonars, echosounders and sub-bottom profilers. The majority of these sources do not ensonify areas where sound levels exceed NMFS' injury thresholds. However, they may produce sound levels that exceed NMFS' continuous and/or pulsed noise thresholds for marine mammal disturbance (i.e., Level B harassment). Sound source noise emissions are discussed here, and representative distances to the 120 dB re 1 µPa threshold are summarized in Table 4.5-12. This table only presents a representative sample, and other vessels will likely have different sound propagation characteristics.

Support vessel operations in the Beaufort and Chukchi Shelf environments may, depending on the type of vessels employed, individually generate 120 dB re 1 µPa zones extending approximately 1 km to 5.4 km (0.6 to 4 mi) (Chorney et al. 2010). For reference, open water ambient noise levels in the Chukchi Sea in

the 10 Hz to 24 kHz frequency band can fall below 100 dB re 1 μPa (Fig 3.19 in O'Neill et al. 2010). Noise generated by research vessel *Mt. Mitchell*, transiting at 10 knots over the Burger prospect during Shell's 2010 Geotechnical Survey, reached 120 dB re 1 μPa at 1.6 km distance. Its sound emission levels increased when operating in dynamic positioning (DP) mode, and the estimated distance to 120 dB re 1 μPa increased to 5.6 km (Chorney et al. 2010).Vessel operations in the shallower coastal areas of the Beaufort Sea produce smaller noise footprints due to reduced low frequency sound propagation in shallower water. Acoustic measurements of nine vessels, including two source vessels, three cable lay vessels, and two crew-change/support vessels were made in 9 m water depth during the Eni/PGS 2008 OBC project (Warner et al. 2008). Their 120 dB re 1 μPa threshold distances ranged from 280 m, for a cable lay vessel to 1,300 m (0.8 mi) for a crew change vessel. The average distance was 718 m (0.43 mi), and that value is considered as representative for support vessels in coastal operations.

Drillship sound levels are discussed in Section 2.3.3. An initial estimate of the 120 dB re 1 μPa threshold distance for drilling from a drillship was based on the source level measurements of the drillship *Noble Discoverer* made in 2009 in the South China Sea (Austin and Warner 2010). Those measurements indicated drilling source levels from 178.5 to 185.4 dB re 1 μPa@1m (10 Hz to 24 kHz). Based on that information, acoustic modeling using Marine Operations Noise Model (MONM, JASCO Applied Sciences) estimated the 120 dB re 1 μPa threshold distance at between 1.5 and 2 km (0.9 and 1.2 mi). Subsequently, Shell's 2012 drilling program SSC measurements were reported in their 2012 90-day report (Austin et al., 2012). Drilling of a 26" diameter hole at Shell's Burger-A site in the Chukchi Sea with no other vessels nearby produced a source level of 181 dB re 1μPa@1m and resulted in a 120 dB re 1 μPa distance of 1.5 km. Drilling with a support vessel alongside increased the distance to 2.7 km. The measurements also included short-term auxiliary activities, including excavation of mudline cellar using an auger style drill system, ice management with an icebreaker, and anchor connections involving use of a tug (*Tor Viking*) to attach cables from the drillship to anchors set on the seafloor to hold the *Noble Discoverer* in place. A summary of measurements for these activities is provided in Table 4.5-12.

Shell's drilling project in the Chukchi Sea in 2015 involved two drill ships and more than ten support vessels. A summary of measurement results from drilling at their Burger J prospect using the semi-submersible drillship *Polar Pioneer*, is given in Table 4.5-13.

Table 4.5-12 Sound level threshold distances for drilling by *Noble Discoverer* and related ancillary activities in the Chukchi Sea during Shell's 2012 drill program. Reproduced from Shell's 2013 program Comprehensive Report.

Drill Site Activity	rms SPL Threshold Radii (m)			
	190 dB re 1 µPa	180 dB re 1 µPa	160 dB re 1 µPa	120 dB re 1 µPa
Drilling 26" hole with *MSV Fennica* on DP alongside*	<10	<10	11	2687
Drilling 26" hole (no ancillary vessels)	< 10	< 10	< 10	1500
Drilling of mudline cellar**	< 10	<10	71	8159
Ice management	< 10	< 10	60	9600**
Anchor connection	<10	20	178	14,069**

* *MSV Fennica* is a 116 m (381-foot) multipurpose icebreaker and supply vessel.
** Extrapolated from maximum measurement range of 8200 m.

Table 4.5-13 Sound level threshold distances for drilling by *Polar Pioneer* and related ancillary activities in the Chukchi Sea during Shell's 2015 drill program. Reproduced from Shell's 2015 program 90-Day Report.

Activity	rms SPL threshold distances (m)							
	190 dB re 1 µPa		180 dB re 1 µPa		160 dB re 1 µPa		120 dB re 1 µPa	
	Best fit	90% fit	Best fit	90% fit	Best fit	90% fit	Best fit	90% fit
Circulating1	0*	0*	0*	0*	0*	0*	870	1,150
Running casing1	0*	0*	<10*	<10*	<10*	<10*	1,330	1,750
Drilling1	0*	0*	0*	0*	0*	0*	2,950	6,150
MLC construction1	<10*	<10*	<10*	<10*	40*	40*	19,050*	20,880*
Anchor handling2	<10**	<10**	<10**	<10**	40**	60**	9,730**	11,140**

*Extrapolated inside of or beyond measurement range from 0.5 km to 16 km.
** Extrapolated inside of or beyond measurement range from 0.1 km to 2.1 km.
1 Measured at Burger J site
2 Measured at Burger V site

Shell's 2015 acoustic analysis also considered the aggregate area ensonified above 120 dB re 1 uPa on a continuous basis due to noise from drilling and all of their support vessels was on average 1264 km^2. This area corresponds to a circle of radius 20.1 km, although the actual shape of the area depends on support vessel location distribution.

Jack-up drill rigs produce lower level of sounds than vessels as the support legs do not effectively transmit vibrations from on-rig equipment into the water. For the purpose of this evaluation, the 120 dB re 1 µPa threshold distance is based on modeled noise levels predicted by a noise model prediction made for a 2014 exploration drilling program contemplated by ConocoPhillips (O'Neill et al. 2012). This modeling assumed a broadband source level of 167 dB re 1 µPa@1m and estimated the 120 dB re 1 µPa threshold distance at 210 m (689 ft.).

Sounds from on-ice vibroseis systems are discussed in Section 2.3.2. Vibroseis source pressure waveforms are typically frequency sweeps below 100 Hz, though strong harmonics may exist to 1.5 kHz, and with signal durations of 5 to 20 seconds. They are presently categorized as continuous-type sounds (Richardson et al. 1995). The measurement of on-ice vibroseis source levels in shallow water is complicated by interference from bottom and surface reflections, and as a consequence there is considerable variability in the published source levels. Holliday measured an on-ice vibroseis source level of 187 dB re 1 µPa@1m, with bandwidth 10 to 70 Hz (Holliday et al. 1984 as discussed in Richardson et al. 1995). While this source level is several decibels higher than those of vessels, its low operating

frequency will lead to shorter horizontal propagation distances. It is expected the maximum levels will be similar to or less than those from the larger vessels. The largest 120 dB re 1 µPa threshold distance for vessels in the Eni/PGS 2008 OBC study was 1,300 m (0.8 mi). That distance is assumed for the vibroseis in this analysis.

The measurements referenced in the preceding discussion are summarized in Table 4.5-14a, providing the expected distances to the 120 dB disturbance threshold for each non-airgun source. These values are used in the impact assessments that follow for each alternative.

Table 4.5-14a Examples of measured distances to 120 dB re 1 µPa for non-airgun sources, from discussion above

Source Type	Distance to 120 dB re 1 µPa
Drillship alone	2-6 km (1.2-3.6 mi)
Jack-up rig alone	210 m (689 ft.)
Support Vessel in Offshore Operation	1.6 km (1 mi)
Drillship with support vessel fleet	20.1 km (12.5 mi)
Support Vessel in Coastal Operation	0.72 km (0.43 mi)
On-ice vibroseis	1.3 km (0.78 mi)

4.5.1.4.5 Direct and Indirect Effects

Under Alternative 2, underwater noise levels will increase in the vicinity of seismic survey and support vessels, drill rigs, and airgun sources. The effects considered here are based on the current NMFS rms sound level thresholds for PTS (auditory injury) and disturbance that were discussed above.

Estimates of Total Surface Areas of Ensonification at Threshold Levels

Table 4.5-14a contains estimates of surface areas ensonified above given threshold levels under Alternative 2 based on the ranges provided in Appendix G. For the purpose of computing these notional areas, the seismic survey activities listed in Table 4.2-1 for Activity Level 1 are distributed among the three environments considered in this EIS. The three 2D/3D surveys and three site clearance or high resolution shallow hazards surveys in the Chukchi Sea are all assumed to be in the mid-depth shelf region; the four exploration surveys and three site clearance or high resolution shallow hazards surveys in the Beaufort Sea are divided between the mid-depth shelf and the shallow-depth coastal regions in the proportions of 3:1 and 2:1 respectively (giving greater representation to the shelf region makes the estimates more precautionary). The source array sizes in the three zones reflect the prevailing configurations for seismic surveys conducted in each region. The percentages are based on nominal surface areas of 263,500 km^2 for the Chukchi Sea portion of the EIS project area and 255,350 km^2 for the Beaufort portion. Of note, the total surface areas do not subtract out either overlap with other isopleths of concurrent source operation or land area where activities are closer to shore. For that reason, the area ensonified over 120 dB re 1 µPa is likely an overestimate (see Figures 4.7 through 4.12 illustrating conceptual examples). Also of note is that Tables 4.5-14 a-c provide percentages of EIS areas ensonified above 120 dB re 1 µPa for all sources (seismic and drilling/support vessel) and separately for just drilling/support vessels. The latter value is used for assessing Alternatives in terms of magnitude of effect for behavioral disturbance because NMFS applies the 120 dB re 1 µPa threshold only to continuous-type noise sources; impulsive sounds from seismic surveys are evaluated with the 160 dB re 1 µPa threshold. The former (area above 120dB for all sources including seismic) is included to be generally illustrative

and to inform the magnitude of effects on the acoustic environment and acoustic habitat (i.e., animals will hear seismic at these levels and the potential to mask acoustic cues exists).

Table 4.5-14b Total Surface Areas (km^2) Ensonified Above Sound Level Thresholds Under Alternative 2, From Average Distances Listed in Table 4.5-11 and 4.5-14a

		Total Surface Area (km²) to sound level (dB re 1 µPa; 90% rms SPL)			
		190	**180**	**160**	**120**
Chukchi Sea Shelf, 25 to 50 m depth					
	3 x ~3200 in³	2.64	26.6	1010	81398
	3 x 40 in³	0.01	0.15	16.4	6973
	1 x drill/support*				1264
	% Chukchi (all sources)	**0.00%**	**0.01%**	**0.39%**	34.02%
	% Chukchi (drill/support* only)				**0.48%**
Beaufort Sea Shelf, ≥15 m depth					
	3 x ~3200 in³	7.44	62.4	1236	52750
	2 x 20 in³	0.00	0.02	3.34	1919
	1 x drill/support*				1264
Beaufort Coastal, <15 m depth					
	1 x 880 in³	0.16	0.74	15.6	661
	1 x 20 in³	0.01	0.06	2.18	134
	% Beaufort (all sources)	**0.00%**	**0.02%**	**0.49%**	22.22%
	% Beaufort (drill/support* only)				**0.50%**
Entire Region					
	all sources	10.26	89.9	2283	146362
	% EIS area (all sources)	**0.00%**	**0.02%**	**0.44%**	28.21%
	% EIS area (drill/support* only)				**0.49%**

*drill/support indicates the combined area ensonified by a drillship and all support vessels.

Table 4.5-14c Total Surface Areas (km^2) Ensonified Above Sound Level Thresholds Under Alternative 3, From Average Distances Listed in Table 4.5-11 and 4.5-14a

		Total Surface Area (km^2) to sound level (dB re 1 µPa; 90% rms SPL)			
		190	**180**	**160**	**120**
Chukchi Sea Shelf, 25 to 50 m depth					
	5 x ~3200 in^3	4.39	44.33	1682.60	135663.59
	5 x 40 in^3	0.02	0.25	27.37	11621.38
	2 x drill/support*				2528
	% Chukchi (all sources)	**0.00%**	**0.02%**	**0.65%**	56.86%
	% Chukchi (drill/support* only)				**0.96%**
Beaufort Sea Shelf, ≥15 m depth					
	4 x ~3200 in^3	9.92	83.16	1648.20	70333.79
	3 x 20 in^3	0.00	0.03	5.01	2878.10
	2 x drill/support*				2528
Beaufort Coastal, <15 m depth					
	2 x 880 in^3	0.32	1.48	31.11	1321.04
	2 x 20 in^3	0.02	0.12	4.35	267.51
	% Beaufort (all sources)	**0.00%**	**0.03%**	**0.66%**	30.28%
	% Beaufort (drill/support* only)				**0.99%**
Entire Region					
	all sources	14.67	129.4	3399	227141
	% EIS area (all sources)	**0.00%**	**0.02%**	**0.66%**	43.78%
	% EIS area (drill/support* only)				**0.97%**

*drill/support indicates the combined area ensonified by a drillship and all support vessels.

Table 4.5-14d Total Surface Areas (km^2) Ensonified Above Sound Level Thresholds Under Alternative 4, 5, and 6, From Average Distances Listed in Table 4.5-11 and 4.5-14a

		Total Surface Area (km^2) to sound level (dB re 1 µPa; 90% rms SPL)			
		190	**180**	**160**	**120**
Chukchi Sea Shelf, 25 to 50 m depth					
	5 x ~3200 in^3	4.39	44.33	1682.60	135663.59
	5 x 40 in^3	0.02	0.25	27.37	11621.38
	4 x drill/support*				5056
	% Chukchi (all sources)	**0.00%**	**0.02%**	**0.65%**	57.81%
	% Chukchi (drill/support* only)				**1.92%**
Beaufort Sea Shelf, ≥15 m depth					
	4 x ~3200 in^3	9.92	83.16	1648.20	70333.79
	3 x 20 in^3	0.00	0.03	5.01	2878.10
	4 x drill/support*				5056
Beaufort Coastal, <15 m depth					
	2 x 880 in^3	0.32	1.48	31.11	1321.04
	2 x 20 in^3	0.02	0.12	4.35	267.51
	% Beaufort (all sources)	**0.00%**	**0.03%**	**0.66%**	31.27%
	% Beaufort (drill/support* only)				**1.98%**
Entire Region					
	all sources	14.67	129.4	3399	232197
	% EIS area (all sources)	**0.00%**	**0.02%**	**0.66%**	44.75%
	% EIS area (drill/support* only)				**1.95%**

*drill/support indicates the combined area ensonified by a drillship and all support vessels.

4.5.1.4.6 Conclusion

Alternative 2 presents the lowest activity level analyzed of the alternatives, but it represents an increase in activity above current levels of activity in the EIS project area. The distances to PTS thresholds are given in Appendix G (summarized in Table 4.5-11) for deep penetration airgun array sources and shallow hazards sources. The 180 dB re 1 µPa distance for deep penetration seismic sources extends out to 2,570 m for 2D and 3D surveys on the Beaufort Shelf based on measurements of 3147 in^3 arrays. All of the sound sources associated with Alternative 2 will ensonify nearby areas above the current marine mammal disturbance threshold of 120 dB re 1 µPa for continuous noise and 160 dB re 1 µPa (90 percent rms) for impulsive noise. Estimated distances to these thresholds for seismic airgun sources are given in Table 4.5-11 and for all other sources in Table 4.5-13a, b, c,. The largest expected distance to the 160 dB re 1 µPa disturbance threshold for airgun sources is 11.4 km (6.8 mi), and to the 120 dB re 1 µPa continuous SPL for non-airgun sources it is the drillship at 10 km (6 mi). The maximum measured 120 dB re 1 µPa radius from airgun sources is 167 km (104 mi) (Austin and Laurinolli, 2007), but the average distance for recent 3-D surveys in the Beaufort and Chukchi Sea is 95 km (59 mi) (Table 4.5-11). The relevance of these disturbance zones to specific marine mammal species is discussed in Sections 4.5.2.4.

Separately, modeled chronic and aggregate effects on acoustic habitat from July through mid-October were substantial at several modeled sites in the Beaufort Sea, with losses of up to 98% of the broadband listening area for mid- and low frequency species and up to 20% of bowhead whale communication space (see Section 4.5.2.4.9 for full explanation of the acoustic habitat analysis). The relevance of these modeled results to specific marine mammal species and their acoustic habitat is discussed in Section 4.5.2.4.

The intensity rating of this alternative is high, as additional exploration activities will introduce sound sources with levels that exceed 200 dB re 1 μPa. Because the exploration activities could continue for several months over successive years, the duration is considered long-term. The spatial extent of these activities is regional, since the distribution of exploration activities over the EIS project area will lead to 25 percent of the EIS project area being exposed to sound levels in excess of 120 dB re 1 μPa. Therefore, the overall impact rating for direct and indirect effects to the acoustic environment under Alternative 2 would be moderate.

4.5.1.5 Water Quality

The EPA has the authority to regulate discharges of pollutants to federal waters of the Beaufort and Chukchi seas under the NPDES program. ADEC has the authority to regulate discharges of pollutants to state waters of the Beaufort and Chukchi seas under the APDES program. Wastewater generated from activities within the EIS project area would be discharged in accordance with the conditions of the applicable NPDES and/or APDES permits, as described in Section 3.1.5.1.

The water quality parameters most likely to be affected by the activities described in the alternatives fall into four categories: temperature and salinity; turbidity and total suspended solids; dissolved metals; and hydrocarbons and other organic contaminants. There are many additional metrics for water quality that could be applied to the EIS project area (e.g., pH, fecal coliform counts, residual chlorine concentrations), but considering the nature of the activities described in the alternatives, these four categories encompass the water quality parameters most likely to reflect the potential effects of the alternatives on long-term productivity and sustainability of valued ecosystem components.

The actions proposed in Alternatives 2, 3, 4, and 5 are defined by four action components and various combinations of mitigation measures. The action components are: seismic surveys, site clearance and shallow hazards surveys, on-ice seismic surveys, and exploratory drilling programs, which are described in detail in Chapter 2 of this EIS. The water quality effects of each action component are analyzed separately for each alternative. Overall, seismic surveys, site clearance and shallow hazards surveys, and on-ice seismic surveys are expected to have negligible impacts on water quality. Effects of exploratory drilling on water quality would depend upon the specific techniques used for exploratory drilling, the location of the activity, and mitigation measures implemented, such as reduced discharge and seasonal prohibitions. For example, construction of gravel artificial islands in nearshore waters would result in different impacts to water quality than would drilling from a floating vessel or a jackup rig in OCS waters (see Section 2.3.3).

In any case, exploratory drilling programs would involve discharges to the marine environment that could result in adverse impacts to water quality. The transport, dispersion, and persistence of materials discharged into the marine environment from exploratory drilling operations have been previously evaluated for several areas of the Alaska Arctic OCS. The general conclusions reached in these studies regarding the transport, dispersion, and persistence of drilling discharges are discussed below (from EPA 2006b):

> *The drilling mud discharge separates into an upper and lower plume. Physical descriptions of effluent dynamics and particle transport differ substantially for the two plumes. Drill cuttings (parent material from the drill hole) are generally coarse materials that are deposited rapidly following discharge and settle within the 100-m radius mixing zone. Discharged drilling*

Habitat Changes/Contamination

Seismic airguns may affect invertebrates and fish (prey species used by birds). However there are very few effects on invertebrates and fish from the airgun noise unless they are within a few feet of the sound source (McCauly 1994). These disturbance effects are highly local and transient and not likely to decrease the availability of prey to any bird species. See Section 4.5.2.2 for effects on fish and Section 4.5.2.1 for effects on lower trophic level species.

Exploratory drilling could directly affect a very small area of benthic habitat with increased turbidity and discharge of drilling cuttings. Given the very small number of sites involved in exploratory drilling under Alternative 2 and the temporary nature of the habitat disturbance, the potential for effects on any bird species is considered negligible.

4.5.2.3.2 Mitigation Measures

Standard mitigation measures could reduce adverse impacts to marine and coastal birds (see Sections 2.4.10 or 4.5.2.4.16 or Appendix E for detail). This includes aircraft flight paths and altitude restrictions to reduce the chance of disturbing marine and coastal birds. Additionally, in order to help avoid causing bird collisions with seismic survey and support vessels, BOEM may require that those vessels minimize the use of high-intensity work lights, especially within the 20-m-bathymetric contour.

Most of the additional mitigation measures considered in this EIS would not appreciably reduce potentially adverse effects on birds except for Additional Mitigation Measures C3 and C4. These two measures would reduce the risk of contamination from discharges and drilling muds, although the reduction in adverse effects relative to the standard mitigation measures would be limited to small numbers of birds and small areas of benthic habitat. Additional mitigation measures are not required under any of the alternatives and do not affect the summary conclusion below.

4.5.2.3.3 Conclusion

Marine and coastal birds are legally protected under the MBTA and two are protected under the ESA. Birds fulfill important ecological roles in the Arctic and are considered to be important or unique resources in a NEPA perspective. In the absence of a large oil spill, the effects of disturbance, injury/mortality, and changes in habitat for marine and coastal birds would likely be temporary, local, and not likely to have population-level effects for any species. The overall effects of oil and gas exploration activities authorized under Alternative 2 on marine and coastal birds would be considered minor according to the impact criteria in Table 4.5-16. Conclusions about impacts to birds in the event of a large oil spill are described in Sections 4.10.6.10 and 4.10.7.10. Impacts are anticipated to be reduced based on the mitigation measures required by BOEM in G&G permits (see Appendix E).

4.5.2.4 Marine Mammals

Noise exposure, habitat degradation, and vessel activity (potentially causing displacement from preferred habitats or, though very unlikely, ship strikes) are the primary mechanisms by which activities associated with oil and gas exploration in the Beaufort and Chukchi Seas could directly or indirectly affect marine mammals. The impacts of anthropogenic noise on marine mammals has been summarized in numerous articles and reports including Richardson et al. (1995), Cato et al. (2004), NRC (2003, 2005), Southall et al. (2007), Nowacek et al. (2007), and Weilgart (2007). The following introduction to general effects of noise from oil and gas exploration activities on marine mammals is drawn largely from these and other available literature. Impacts specific to the marine mammal species of interest in the EIS project area are discussed and evaluated separately. Because the occurrence of a large oil spill is a highly unlikely event, it is not part of the proposed action for any alternative. However, in the highly unlikely event a large spill were to occur, it could result in adverse impacts on marine mammals discussed in this section. The oil

spill analysis is not contained in the sections that analyze direct and indirect effects of the alternatives on marine mammals; rather, it is discussed and analyzed separately in Section 4.10 of this EIS.

In this section of the EIS, a general discussion of the potential effects of the various activities on marine mammals is presented first. Following this general discussion, more specific examples and information are presented for the different species or marine mammal groups, where available. Finally, an analysis of the standard and additional mitigation measures is presented for each species or group of marine mammals, as well as analysis for mitigation measures dismissed from further implementation consideration. The impact criteria for marine mammals are outlined for magnitude or intensity, duration, extent, and context in Table 4.5-18.

Table 4.5-18 Impact Criteria for Marine Mammals

Type of effect	Impact Component	Effects Summary	
Behavioral disturbance	Magnitude or Intensity	Low	Changes in behavior due to exploration activity may not be noticeable; animals remain in the vicinity; Level B take of marine mammals is not anticipated
		Medium	Noticeable change in behavior due to exploration activity; animals move away from activity area; Level B take of marine mammals expected, number of individuals taken is less than 30% of population
		High	Level B take of more than 30% of the individuals in the population expected
	Duration	Temporary	Temporary effect that lasts days to 1 month
		Interim	Temporary effect that lasts 1 to 6 months. Impacts would be frequent or extend for longer time periods (an entire project season).
		Long-term	Effects that last more than 6 months (i.e., one season) in a given year or multi-month effects that recur over multiple successive years.
	Geographic Extent	Local	Impacts limited geographically; <10% of EIS project area affected
		Regional	Affects resources beyond a local area, potentially throughout the EIS project area
		State-wide	Affects resources beyond the EIS project area
	Context	Common	Affects usual or ordinary resources in the EIS project area; species are not listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA; impacts *will not* occur in times or areas of specific importance for affected species (e.g., feeding, calving areas, migratory corridor) or across a large portion of the range of a resident population
		Important	1) Species are listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA but do not also have impacts to important areas, OR 2) Species are *not* listed in this manner, but species abundance trend is declining or, impacts *will* occur in times or areas of specific importance for affected species (e.g., feeding, calving areas, migratory corridor) or across a large portion of the range of a resident population.
		Unique	1) Species are listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA and; impacts *will* occur in times or areas of specific importance for affected species (e.g., feeding, calving areas, migratory corridor) or across a large portion of the range of a resident population OR 2) Species is not listed, but species is declining and impacts will occur in areas of specific importance.
Injury and mortality	Magnitude or Intensity	Low	No noticeable incidents of injury or mortality
		Medium	Few injuries may occur
		High	Incident of mortality or multiple incidences of injury
	Duration	Temporary	Injury to affected animal(s) lasts days to 1 month; animal reverts back to pre-activity condition once healed from injury
		Interim	Incidences of injury of affected animal(s) lasts 1 to 6 months; animal reverts back to pre-activity condition once healed from injury
		Long-term	Mortality of animal(s) or incidences of injury persist for more than 6 months; Injury is permanent in some cases
	Geographic Extent	Local	Impacts local; would not extend to a broad region or sector of the population
		Regional	Impacts would occur beyond a local area
		State-wide	Affects resources beyond the region or EIS project area

Type of effect	Impact Component	Effects Summary	
	Context	**Common**	Affects usual or ordinary resources in the EIS project area; species are not listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA
		Important	Species is listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA but the population is stable or increasing
		Unique	Species are listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA and the population is decreasing
Habitat alterations	Magnitude or Intensity	**Low**	Changes in resource character may not be measurable or noticeable
		Medium	Noticeable changes in resource character
		High	Acute or obvious changes in resource character
	Duration	**Temporary**	Habitat would be impacted for days to 1 month; no permanent changes to habitat
		Interim	Habitat would be impacted from 1 to 6 months; minimal, temporary alterations to marine mammal habitat
		Long-term	Habitat would be impacted for more than 6 months (i.e., one season); potential for permanent changes to marine mammal habitat
	Geographic Extent	**Local**	Impacts limited geographically; <10% of EIS project area affected
		Regional	Affects resources beyond a local area, potentially throughout the EIS project area
		State-wide	Affects resources beyond the region or EIS project area
	Context	**Common**	Affects usual or ordinary resources in the EIS project area; species are not listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA
		Important	1) Species are listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA but do not also have impacts to important areas, OR 2) Species are *not* listed in this manner, but species abundance trend is declining or, impacts *will* occur in times or areas of specific importance for affected species (e.g., feeding, calving areas, migratory corridor) or across a large portion of the range of a resident population.
		Unique	1) Species are listed as threatened or endangered (or proposed for listing) under the ESA and/or as depleted under the MMPA and; impacts *will* occur in times or areas of specific importance for affected species (e.g., feeding, calving areas, migratory corridor) or across a large portion of the range of a resident population OR 2) Species is not listed, but species is declining and impacts will occur in areas of specific importance.

4.5.2.4.1 General Effects of Noise on Marine Mammals

Marine mammals use hearing and sound transmission to perform vital life functions. Sound (hearing and vocalization/echolocation) serves four primary functions for marine mammals, including: (1) providing information about their environment; (2) communication; (3) prey detection; and (4) predator detection. Introducing sound into the ocean environment could disrupt those functions. The distance from oil and gas exploration activities at which noises are audible depends upon source levels, frequency, ambient noise levels, the propagation characteristics of the environment, and sensitivity of the receptor (Richardson et al. 1995, Nowacek et al. 2007).

In assessing potential effects of noise, Richardson et al. (1995) suggested four criteria for defining zones of influence:

Zone of audibility – the area within which the marine mammal might hear the noise. Marine mammals as a group have functional hearing ranges of 10 Hz to 180 kHz, with best thresholds near 40 dB (Ketten 1998, Kastak et al. 2005, Southall et al. 2007). These data show reasonably consistent patterns of hearing sensitivity within each of four groups: small odontocetes (such as the harbor porpoise), medium-sized odontocetes (such as the beluga and killer whales), large cetaceans (such as bowhead whales), and pinnipeds.

Zone of responsiveness – the area within which the animal reacts behaviorally or physiologically. The behavioral responses of marine mammals to sound depend on: 1) the acoustic characteristics

of the noise source; 2) the physical and behavioral state of animals at time of exposure; 3) the ambient acoustic and ecological characteristics of the environment; and 4) the context of the sound (e.g., whether it sounds similar to a predator) (Richardson et al. 1995, Southall et al. 2007). Temporary behavioral effects, however, often merely show that an animal heard a sound and may not indicate lasting consequences for exposed individuals (Southall et al. 2007). Additionally, in the context of the MMPA, not all responses will rise to the level of a "take;" however, NMFS recognizes some responses in certain situations can rise to this level (Southall et al. 2013).

Zone of masking – the area within which the noise may interfere with detection of other sounds, including communication calls, prey sounds, or other environmental sounds.

Zone of hearing loss, discomfort, or injury – the area within which the received sound level is potentially high enough to cause discomfort or tissue damage to auditory or other systems. This includes temporary threshold shifts (TTS, temporary loss in hearing) or permanent threshold shifts (PTS, permanent loss in hearing at specific frequencies or deafness). Non-auditory physiological effects or injuries that theoretically might occur in marine mammals exposed to strong underwater sound include stress, neurological effects, bubble formation, resonance effects, and other types of organ or tissue damage.

4.5.2.4.2 Potential Effects of Noise from Airguns

The effects of airgun noise on marine mammals could include one or more of the following: tolerance; masking of natural sounds; behavioral disturbance; temporary or permanent hearing impairment; or non-auditory physical or physiological effects (Richardson et al. 1995, Gordon et al. 2004, Nowacek et al. 2007, Southall et al. 2007). The effects of noise on marine mammals are highly variable, often depending on species and contextual factors (Ellison et al. 2012, Richardson et al. 1995).

Tolerance

Richardson et al. (1995) defined tolerance as the occurrence of marine mammals in areas where they are exposed to human activities or manmade noise. In many cases, tolerance develops by the animal habituating to the stimulus (i.e., the gradual waning of responses to a repeated or ongoing stimulus), but because of ecological or physiological requirements, many marine animals may need to remain in areas where they are exposed to chronic stimuli (Richardson et al. 1995). Pulsed sounds from airguns are often detectable in the water at distances of tens of kilometers, without necessarily eliciting behavioral responses. Numerous studies have shown that marine mammals at distances over a few kilometers from operating seismic vessels may show no apparent response (Richardson et al. 1995). That is often true even when pulsed sounds must be readily audible to the animals based on measured received levels and the hearing sensitivity of that mammal group. Although various baleen whales, toothed whales, and (less frequently) pinnipeds have been shown to temporarily react behaviorally to airgun pulses under some conditions, at other times, marine mammals of all three types have shown no overt reactions (Richardson et al. 1995, Stone 2003, Stone and Tasker 2006, Moulton et al. 2005, MacLean and Koski 2005).

Masking

Masking occurs when biologically meaningful sounds (e.g., communication, predator or prey detection, navigation, other environmental cues) are obscured by ambient or anthropogenic noise (Richardson et al. 1995, Clark et al. 2009). Introduced underwater sound will, through masking, reduce the effective communication distance of a marine mammal species if the frequency of the source is close to that used by the marine mammal and if the anthropogenic sound is present for a substantial period of time (Richardson et al. 1995).

Marine mammals are highly dependent on sound, and their ability to recognize sound signals amid other noise is important in communication, predator and prey detection, navigation and sensing other important environmental cues, and, in the case of toothed whales, echolocation. Even in the absence of manmade

sounds, the sea is usually noisy. Background ambient noise often interferes with or masks the ability of an animal to detect a sound signal even when that signal is above its absolute hearing threshold. Natural ambient noise includes contributions from wind, waves, precipitation, other animals, and (at frequencies above 30 kHz) thermal noise resulting from molecular agitation (Richardson et al. 1995). Based on autonomous acoustic recordings from September 2006 to June 2009 north of Barrow, Alaska, on the continental slope between the Beaufort and Chukchi Seas, mean monthly spectrum levels (selected to exclude impulsive events) show that months with open-water had the highest noise levels (80-83 dB re: 1 μPa^2/Hz at 20-50 Hz), months with ice coverage had lower spectral levels (70 dB at 50 Hz), and months with both ice cover and low wind speeds had the lowest noise levels (65 dB at 50 Hz). Background noise also can include sounds from human activities. Masking of natural sounds can result when human activities produce high levels of noise. Conversely, if the background level of underwater noise is high (e.g., on a day with strong wind and high waves), an anthropogenic noise source will not be detectable as far away as would be possible under quieter conditions and will itself be masked.

Although some degree of masking is inevitable when high levels of manmade broadband sounds are introduced into the sea, marine mammals have evolved systems and behavior that function to reduce the impacts of masking. Structured signals, such as the echolocation click sequences of small toothed whales, may be readily detected even in the presence of strong background noise because their frequency content and temporal features usually differ strongly from those of the background noise (Au and Moore 1988, 1990). The components of background noise that are similar in frequency to the sound signal in question primarily determine the degree of masking of that signal.

Redundancy and context can also facilitate detection of weak signals. These phenomena may help marine mammals detect weak sounds in the presence of natural or manmade noise. Most masking studies in marine mammals present the test signal and the masking noise from the same direction. The sound localization abilities of marine mammals suggest that, if signal and noise come from different directions, masking would not be as severe as the usual types of masking studies might suggest (Richardson et al. 1995). The dominant background noise may be highly directional if it comes from a particular anthropogenic source such as a ship or industrial site. Directional hearing may substantially reduce the masking effects of these noises by improving the effective signal-to-noise ratio. In the cases of high-frequency hearing by the beluga whale and killer whale, empirical evidence confirms that masking depends strongly on the relative directions of arrival of sound signals and the masking noise (Penner et al. 1986, Dubrovskiy 1990, Bain et al. 1993, Bain and Dahlheim 1994). Toothed whales and probably other marine mammals as well, have additional capabilities besides directional hearing that can facilitate detection of sounds in the presence of background noise. There is evidence that some toothed whales can shift the dominant frequencies of their echolocation signals from a frequency range with a lot of ambient noise toward frequencies with less noise (Au et al. 1974, 1985; Moore and Pawloski 1990; Thomas and Turl 1990; Romanenko and Kitain 1992; Lesage et al. 1999). A few marine mammal species are known to increase the source levels or alter the frequency of their calls in the presence of elevated sound levels (Dahlheim 1987; Au 1993; Lesage et al. 1993, 1999; Terhune 1999; Foote et al. 2004; Parks et al. 2007, 2009; Di Iorio and Clark 2009; Holt et al. 2009).

These data demonstrating adaptations for reduced masking pertain mainly to the very high frequency echolocation signals of toothed whales. There is less information about the existence of corresponding mechanisms at moderate or low frequencies or in other types of marine mammals. For example, Zaitseva et al. (1980) found that, for the bottlenose dolphin, the angular separation between a sound source and a masking noise source had little effect on the degree of masking when the sound frequency was 18 kHz, in contrast to the pronounced effect at higher frequencies. Directional hearing has been demonstrated at frequencies as low as 0.5 to 2 kHz in several marine mammals, including killer whales (Richardson et al. 1995). This ability may be useful in reducing masking at these frequencies. In summary, high levels of noise generated by anthropogenic activities may act to mask the detection of weaker biologically important sounds by some marine mammals. This masking may be more prominent for lower frequencies.

For higher frequencies, such as that used in echolocation by toothed whales, several mechanisms are available that may allow them to reduce the effects of such masking.

Although there is little data describing the ultimate effects of masking on animals, there can be a measurable loss of communication space that would likely be of more concern for low-frequency species (mysticetes) from lower frequency sources, both because of the communication strategies used by mysticetes (they can communicate over 100s of kilometers for days) and the physical propagation properties of lower frequency sounds (less absorption). Analysis of distant (450 to 2800 km) seismic survey sounds and Antarctic blue and fin whale songs suggest that increased background noise levels decrease potential communication distances by 29 to 40 percent (Gedamke 2011). Vessel noise in a heavily trafficked region off New England may have diminished right whale communication space by an estimated 63 to 67 percent (Hatch et al. 2012). Some whales are known to continue calling in the presence of seismic pulses; however, observers typically note some proximity around the source within which the calls decrease in number or become less frequent (Richardson et al. 1986, McDonald et al. 1995, Greene et al. 1999, Nieukirk et al. 2004, Di Iorio and Clark 2009). Additionally, as described above, some marine mammals, such as the small toothed whales communicate within frequency bands that are quite different from the frequencies of background sounds. Marine mammals that are able to use directional hearing may also be less impacted by masking effects. The greatest limiting factor in estimating impacts of masking is a lack of understanding of the spatial and temporal scales over which marine mammals actually communicate, although some estimates of distance are possible using signal and receiver characteristics. Estimates of communication masking, however, depend on assumptions for which data are currently inadequate (Clark et al. 2009).

The *Cumulative Effects of Anthropogenic Underwater Sound on Marine Mammals* is a University of California project sponsored by British Petroleum (BP) for which an expert committee was convened and tasked with developing a model for systematically evaluating the potential effects of multiple sound sources. Although additional work is needed, the model provides a first step to better understanding the cumulative impacts of the sound sources associated with oil and gas exploration (Streever et al. 2012). After outlining a quantitative method, the committee conducted a trial to assess impacts to bowheads based broadly on operational conditions in the Alaskan Beaufort in September and October of 2008. The model results highlighted some of the limitations of the model, which primarily arose from the simplifying assumptions necessary due to the lack of empirical data. However, the model also illustrated how these types of tools can be used for improved, scenario-driven, evaluations of multiple-source sounds (e.g., to compare sound exposure or extra distance traveled off migration path given different individual sound avoidance strategies). Further, the committee recognized the complexities and resource cost of developing and implementing a quantitative model-based framework, and how they may constrain the regular use of such models. However, the committee continues to work on a more qualitative method for more routine use and also to further flesh out the quantitative method.

Through the process of developing this FEIS, commenters recommended that NMFS include a mechanism for better assessing the chronic and aggregate effects of the Alternatives explored in this EIS. NMFS designed and conducted such an analysis and Section 4.5.2.4.9 includes a description of the results and limitations of this first-order assessment. Results predict losses in broadband listening area and bowhead communication space at 10 specific receiver sites when averaged over July through mid-October.

Disturbance Reactions

Reactions to sound, if any, depend on species, state of maturity, experience, current activity, reproductive state, time of day, environmental conditions, and many other factors (Richardson et al. 1995, Stone and Tasker 2006). Responses also depend on whether an animal is less likely (habituated) or more likely (sensitized) to respond to sound exposure (Southall et al. 2007). Responses to anthropogenic sounds are highly variable. Meaningful interpretation of behavioral responses should not only consider the relative

magnitude and severity of reactions but also the relevant acoustic, contextual variables (e.g., proximity, subject experience and motivation, duration, or recurrence of exposure), and ecological variables (Southall et al. 2007).

If a marine mammal reacts briefly to an underwater sound by minimally changing its behavior or moving a short distance, the impacts of the change are unlikely to be substantial to the individual and will not impact the stock or the species as a whole. However, if a sound source displaces marine mammals from an important feeding or breeding area for a prolonged period, impacts on the animals could be noteworthy. Data on short-term reactions (or lack of reactions) do not necessarily provide information about long-term effects. It is not known whether impulsive noises affect marine mammal reproductive rates or distribution and habitat use in subsequent days or years. However, the Western Arctic stock of bowhead whales has been increasing at approximately 3.7 percent per year (Givens et al. 2013), during a period of exposure to exploration activities in the Beaufort and Chukchi seas since the late 1960s. Additionally, enough information is available to make a reasoned choice among alternatives. Further, impacts to other arctic marine mammal species' reproductive rates or stock sizes have not been documented.

Disturbance includes a variety of effects, including subtle changes in behavior, more conspicuous changes in activities, and displacement. Observable reactions of marine mammals to sound include attraction to the sound source, increased alertness, modification to their own sounds, cessation of feeding or interacting, alteration in swimming or diving behavior (change direction or speed), short or long-term habitat abandonment (deflection, short or long-term avoidance), and, possibly, panic reactions, such as stampeding or stranding (Nowacek et al. 2007, Richardson et al. 1995, Southall et al. 2007).

Because the physiological and behavioral responses of the majority of the marine mammals exposed to anthropogenic sound cannot be detected or measured (not all responses visible external to animal, portion of exposed animals underwater [i.e., not visible], many animals located many miles from observers and covering very large area, etc.) and because NMFS must authorize take prior to the impacts to marine mammals, a method is needed to estimate the number of individuals that will be taken, pursuant to the MMPA, based on the proposed action. To this end, NMFS developed acoustic thresholds that estimate at what received sound levels the Level B Harassment, Level A Harassment, and mortality of marine mammals would occur from different types of sounds. The current NMFS acoustic threshold for Level B behavioral harassment is 160 dB re 1 µPa rms received level for impulse noises (such as airgun pulses) and 120 dB re 1 µPa rms for continuous sounds (such as drill ships and icebreaking).

Noise Induced Threshold Shift

Animals exposed to intense sound may experience reduced hearing sensitivity for some period of time following exposure. This increased hearing threshold is known as noise induced threshold shift (TS). The amount of TS incurred is influenced by amplitude, duration, frequency content, temporal pattern, and energy distribution of the noise (Kryter 1985, Richardson et al. 1995, Southall et al. 2007). It is also influenced by characteristics of the animal, such as behavior, age, history of noise exposure, and health. The magnitude of TS generally decreases over time after noise exposure, and, if it eventually returns to zero, it is known as temporary threshold shift (TTS). If TS does not return to zero after some time, it is known as permanent threshold shift (PTS). Sound levels associated with TTS onset are generally considered to be below the levels that will cause PTS, which is considered to be auditory injury.

NMFS has established acoustic thresholds that identify the received sound levels above which permanent hearing impairment or other injury could potentially occur (Level A take). Historically, NMFS identified 180 and 190 dB re 1 µPa (rms) for cetaceans and pinnipeds, respectively as the received levels above which, in the view of a panel of bioacoustics specialists convened by NMFS before TTS measurements (which inform PTS predictions) for marine mammals became available, one could not be certain that there would be no injurious effects, auditory or otherwise, to marine mammals. As discussed in Section 4.2.6, NMFS recently finalized revisions to these acoustic thresholds (NOAA 2016). The new auditory

injury thresholds utilize dual metrics, one for peak pressure sound pressure level (PK), and one for cumulative SEL (SEL_{cum}) that takes into consideration the duration of the exposure within a day. Calculating exposures with the metric that incorporates duration is slightly more complicated, but it is still likely that most marine mammals avoid ships and/or seismic operations at distances that likely avoid PTS, or evern TTS, onset. In addition, monitoring and mitigation measures often implemented during seismic surveys are designed to detect marine mammals near the airgun array to avoid exposure to sound pulses of a level or duration that may cause hearing impairment. If animals do incur TTS, it is a temporary and reversible phenomenon unless exposure exceeds the TTS-onset threshold by an amount sufficient to cause PTS which, while unlikely, is still possible.

In a study on monkeys, Lonsbury-Martin et al. (1987) found that the long-lasting nature of changes in neural responsiveness suggests that each TTS episode may produce an increment of damage to the ear and eventually contribute to measurable PTS. This was tested by exposing monkeys to short-lasting TTS sound repeatedly for many months and then comparing their cochlear ducts for hearing loss damages. Hamernik et al. (2002) compared the inferior colliculus in chinchillas that were exposed to three different thresholds of noise exposure and found there was a consistent relationship between PTS and TTS. The following subsections summarize the available data on noise-induced hearing impairment in marine mammals.

Temporary Threshold Shift

TTS is the mildest form of hearing impairment that can occur during exposure to sound (Kryter 1985). It is not considered to represent physical injury, as hearing sensitivity fully recovers after the sound ends. TTS is defined as a temporary, reversible increase in the threshold of audibility at a specified frequency or portion of an individual's hearing range above a previously established reference level. Sounds must be temporarily louder for an animal to hear them. The amount of TTS is customarily expressed in decibels (ANSI 1995; Yost 2007). Based on data from cetacean TTS measurements (see Finneran 2015 for a review), a TTS of 6 dB is considered the minimum threshold shift clearly larger than any day-to-day or session-to-session variation in a subject's normal hearing ability (Schlundt et al. 2000; Finneran et al. 2000; Finneran et al. 2002). Several physiological mechanisms are thought to be involved with inducing TTS. These include reduced sensitivity of sensory hair cells in the inner ear, changes in the chemical environment in the sensory cells, residual middle-ear muscular activity, displacement of inner ear membranes, increased blood flow, and post-stimulatory reduction in efferent and sensory neural output (Kryter 1994, Ward 1997, Southall et al. 2007).

The magnitude of TTS depends on the level, duration, and frequency (kHz) associated with the noise exposure (Kryter 1985, Richardson et al. 1995, Southall et al. 2007). TTS has only been studied in captive odontocetes and pinnipeds (reviewed in Finneran 2015 and in Appendix B). No hearing or TTS data are available for mysticete species. Few data are available for marine mammals regarding exposure to multiple pulses of sound during seismic surveys (see Lucke et al. 2009 and Finneran et al. 2015). For species or groups of marine mammals for which studies have been conducted, those data or information are presented in the specific subsections below. It is difficult for researchers to present controlled exposures and conduct measurements in the wild, and it is not possible to conduct laboratory experiments on large baleen whales. Using extrapolated data from other species is considered an acceptable proxy for determining TTS in baleen whales or other groups where hearing data do not exist (Southall et al. 2007).

For toothed whales, experiments on a bottlenose dolphin (*Tursiops truncates*) and beluga whale showed that exposure to a single watergun impulse at a received level of 207 kPa (or 30 psi) peak-to-peak (p-p), which is equivalent to 228 dB re 1 mPa (p-p), resulted in a 7 and 6 dB TTS in the beluga whale at 0.4 and 30 kHz, respectively. Thresholds returned to within 2 dB of the pre-exposure level within 4 minutes of the exposure (Finneran et al. 2002). No TTS was observed in the bottlenose dolphin. Finneran et al. (2005) further examined the effects of tone duration on TTS in bottlenose dolphins. Bottlenose dolphins were exposed to 3 kHz tones (non-impulsive) for periods of 1, 2, 4 or 8 seconds (s), with hearing tested at 4.5

kHz. For 1-s exposures, TTS occurred with SELs of 197 dB, and for exposures >1 s, SEL >195 dB resulted in TTS (SEL is equivalent to energy flux, in dB re 1 mPa2-s). At an SEL of 195 dB, the mean TTS (4 minutes (mins) after exposure) was 2.8 dB. Finneran et al. (2005) suggested that an SEL of 195 dB is the likely threshold for the onset of TTS in dolphins and belugas exposed to tones of durations 1–8 s (i.e., TTS onset occurs at a near constant SEL, independent of exposure duration). That implies that, at least for non-impulsive tones, a doubling of exposure time results in a 3 dB lower TTS threshold. However, the assumption that, in marine mammals, the occurrence and magnitude of TTS is a function of cumulative acoustic energy (SEL) is probably an oversimplification. Kastak et al. (2005) reported preliminary evidence from pinnipeds that, for prolonged non-impulse noise, higher SELs were required to elicit a given TTS if exposure duration was short than if it was longer, i.e., the results were not fully consistent with an equal-energy model to predict TTS onset. Mooney et al. (2009a) showed this in a bottlenose dolphin exposed to octave-band non-impulse noise ranging from 4 to 8 kHz at SPLs of 130 to 178 dB re 1 mPa for periods of 1.88 to 30 minutes (min). Higher SELs were required to induce a given TTS if exposure duration was short than if it was longer. Exposure of the aforementioned bottlenose dolphin to a sequence of brief sonar signals showed that, with those brief (but non-impulse) sounds, the received energy (SEL) necessary to elicit TTS was higher than was the case with exposure to the more prolonged octave-band noise (Mooney et al. 2009b). Those authors concluded that, when using (non-impulse) acoustic signals of duration ~0.5 s, SEL must be at least 210–214 dB re 1 mPa2-s to induce TTS in the bottlenose dolphin. The most recent studies conducted by Finneran et al. also support the notion that exposure duration has a more substantial influence compared to SPL as the duration increases, and that TTS growth data are better represented as functions of SPL and duration rather than SEL alone (Finneran et al. 2010a, 2010b). In addition, Finneran et al. (2010b) conclude that when animals are exposed to intermittent noises, there is recovery of hearing during the quiet intervals between exposures through the accumulation of TTS across multiple exposures. Such findings suggest that when exposed to multiple seismic pulses, partial hearing recovery also occurs during the seismic pulse intervals.

Permanent Threshold Shift

PTS is defined as “irreversible elevation of the hearing threshold at a specific frequency” (Yost 2000). It involves physical damage to the sound receptors in the ear and can result in either total or partial deafness or impaired ability to hear sounds in specific frequency ranges (Kryter 1985). Some causes of PTS are severe extensions of effects underlying TTS (e.g., irreparable damage to sensory hair cells). Others involve different mechanisms, for example, exceeding the elastic limits of certain tissues and membranes in the middle and inner ears and resultant changes in the chemical composition of inner ear fluids (Ward 1997, Yost 2000). The onset of PTS is determined by pulse duration, peak amplitude, rise time, number of pulses, inter-pulse interval, location, species and health of the receivers ear (Ketten 1994).

The relationships between TTS and PTS thresholds have not been studied in marine mammals, and there is currently no evidence that exposure to airgun pulses can cause PTS in any marine mammal, however there has been speculation about that possibility (Richardson et al. 1995, Gedamke et al. 2008).

Section 4.2.6.3 outlines NMFS final revisions to auditory injury thresholds. NMFS applied these thresholds to the types of sources analyzed in this EIS (seismic airguns and drilling sources of similar size) and found that the resulting distances at which injurious exposures could not be ruled out (i.e., those at which PTS might be incurred) were similar to those calculated using the 180 and 190-dB historical thresholds, meaning that the revisions to the auditory injury thresholds do not notably change any of the conclusions articulated in earlier versions of the EIS.

It is unlikely that a marine mammal would remain close enough to a large airgun array long enough to incur PTS. The levels of successive pulses received by a marine mammal will increase and then decrease gradually as the seismic vessel approaches, passes and moves away, with periodic decreases also caused when the animal goes to the surface to breath, reducing the probability of the animal being exposed to sound levels large enough to elicit PTS.

Non-Auditory Physiological Effects

Non-auditory physiological effects or injuries could include stress, neurological effects, bubble formation, and other types of organ or tissue damage. If any such effects do occur, they may be limited to unusual situations when animals might be exposed at close range for unusually long periods. Issues that may arise from adverse stress responses over a period of time include accelerated aging, sickness-like symptoms, suppression of the immune system, elevated stress hormones, and suppression of reproduction (physiologically and behaviorally) (Wright et al. 2008).

There are times during an animal's life when they have lower reserves and are more vulnerable to impacts from stressors. For example, if a mammal is stressed at the end of a feeding season just prior to a long distance migration, it may have sufficient energy reserves to cope with the stress. If stress occurs at the end of a long migration or fasting period, energy reserves may not be sufficient to adequately cope with the stress (Tyack 2008, McEwen and Wingfield 2003, and Romano et al. 2004).

Young animals (and fetuses) are sensitive to neurological consequences of the stress response and can suffer permanent neurological alterations. Deep diving marine mammals may also be more sensitive to neurological consequences of stress responses (Wright et al. 2008).

In an examination of beaked whales (which are not found in the Beaufort and Chukchi seas) that were stranded in association with military exercises involving sonar (psychological stressor), intracellular globules composed of acute phase proteins were found in cells in six out of eight livers examined, therefore, there is some indication that a stress response was partly involved (Wright et al. 2008). Hypoxia may also pose an issue for marine mammals being exposed to stressors at depth, due to increases in heart rate, which in turn causes an increase in oxygen consumption. This added oxygen demand could push the whales over the physiological edge. The combination of both the psychological stressor and the physiological stressor may have detrimental consequences (Wright et al. 2008). A study by Rolland et al. (2012) found a decrease in baseline concentrations of faecal adrenal glucocorticoids (fGCs) (a corticosteroid chemical compound produced as a physiological response to stress) in North Atlantic right whales associated with a 6 dB decrease in overall noise levels when ship traffic was reduced in the Bay of Fundy following the events of September 11, 2001. This reduced corticosteriod concentration suggests a reduced stress level in whales as a result of reduced noise exposure. However, it is difficult to definitively link chronic stress responses to long-term, detrimental health effects in large whales. Nonetheless, the study by Rolland et al. (2012) indicates that there is the potential for certain individuals to exhibit stress responses to anthropogenic sounds. Classic stress responses begin when an animal's central nervous system perceives a potential threat to its homeostasis. That perception triggers stress responses regardless of whether a stimulus actually threatens the animal; the mere perception of a threat is sufficient to trigger a stress response (Moberg 2000, Sapolsky et al. 2005, Seyle 1950). Once an animal's central nervous system perceives a threat, it mounts a biological response or defense that consists of a combination of the four general biological defense responses: behavioral responses; autonomic nervous system responses; neuroendocrine responses; or immune responses.

In the case of many stressors, an animal's first and most economical (in terms of biotic costs) response is behavioral avoidance of the potential stressor or avoidance of continued exposure to a stressor. An animal's second line of defense to stressors involves the sympathetic part of the autonomic nervous system and the classical "fight or flight" response which includes the cardiovascular system, the gastrointestinal system, the exocrine glands, and the adrenal medulla to produce changes in heart rate, blood pressure, and gastrointestinal activity that humans commonly associate with "stress." The frequency of such short-term exposures and responses may have an important role on whether or not there would be a significant short- or long-term effect on an animal's welfare. Baker et al. (1983) described two avoidance techniques whales used in response to vessels: horizontal avoidance (faster swimming, and fewer long dives) and vertical avoidance (swimming more slowly but remaining submerged more frequently. Watkins et al. (1981) found that humpback and fin whales appeared startled and increased

their swimming speed to move away from the approaching vessel. Johada et al. (2003) studied responses of fin whales in feeding areas when they were closely approached by inflatable vessels. The study concluded that close vessel approaches caused the fin whales to swim away from the approaching vessel and to stop feeding. These animals also had increases in blow rates and spent less time at the surface. This suggests increases in metabolic rates, which may indicate a stress response. All these responses can manifest as a stress response in which the mammal undergoes physiological changes with chronic exposure to stressors, it can interrupt essential behavioral and physiological events, alter time budget, or a combination of all these stressors (Frid and Dill 2002, Sapolsky 2000). All of these responses to stressors can cause an abandonment of an area, reduction in reproductive success, and even death (Mullner et al. 2004, and Daan et al. 1996).

An animal's third line of defense to stressors involves its neuroendocrine or sympathetic nervous systems; the system that has received the most study has been the hypothalmus-pituitary-adrenal system (also known as the HPA axis in mammals or the hypothalamus-pituitary-interrenal axis in fish and some reptiles). Unlike stress responses associated with the autonomic nervous system, virtually all neuro-endocrine functions that are affected by stress – including immune competence, reproduction, metabolism, and behavior – are regulated by pituitary hormones. Stress-induced changes in the secretion of pituitary hormones have been implicated in failed reproduction (Moberg 1987, Rivier 1995), altered metabolism (Elasser et al. 2000), reduced immune competence (Blecha 2000), and behavioral disturbance. Increases in the circulation of glucocorticosteroids (cortisol, corticosterone, and aldosterone in marine mammals; see Romano et al. 2004) have been equated with stress for many years.

The primary distinction between stress (which is adaptive and does not normally place an animal at risk) and distress is the biotic cost of the response. During a stress response, an animal uses glycogen stores that can be quickly replenished once the stress is alleviated. In such circumstances, the cost of the stress response would not pose a risk to the animal's welfare. However, when an animal does not have sufficient energy reserves to satisfy the energetic costs of a stress response, energy resources must be diverted from other biotic functions, which impair those functions that experience the diversion. For example, when mounting a stress response diverts energy away from growth in young animals, those animals may experience stunted growth. When mounting a stress response diverts energy from a fetus, an animal's reproductive success and fitness will suffer. In these cases, the animals will have entered a pre-pathological or pathological state which is called "distress" (sensu Seyle 1950) or "allostatic loading" (sensu McEwen and Wingfield 2003). This pathological state will last until the animal replenishes its biotic reserves sufficient to restore normal function. Note that these examples involved a long-term (days or weeks) stress response exposure to stimuli.

Relationships between these physiological mechanisms, animal behavior, and the costs of stress responses have also been documented fairly well through controlled experiment; because this physiology exists in every vertebrate that has been studied, it is not surprising that stress responses and their costs have been documented in both laboratory and free-living animals (for examples see, Holberton et al. 1996, Hood et al. 1998, Jessop et al. 2003, Krausman et al. 2004, Lankford et al. 2005, Reneerkens et al. 2002, Thompson and Hamer 2000). .

For example, Jansen (1998) reported on the relationship between acoustic exposures and physiological responses that are indicative of stress responses in humans (e.g., elevated respiration and increased heart rates). Jones (1998) reported on reductions in human performance when faced with acute, repetitive exposures to acoustic disturbance. Trimper et al. (1998) reported on the physiological stress responses of osprey to low-level aircraft noise, while Krausman et al. (2004) reported on the auditory and physiology stress responses of endangered Sonoran pronghorn to military overflights. Smith et al. (2004a, 2004b) identified noise-induced physiological transient stress responses in hearing-specialist fish (i.e., goldfish) that accompanied short- and long-term hearing losses. Welch and Welch (1970) reported physiological and behavioral stress responses that accompanied damage to the inner ears of fish and several mammals.

Hearing is one of the primary senses marine mammals use to gather information about their environment and communicate with conspecifics. Although empirical information on the relationship between sensory impairment (TTS, PTS, and acoustic masking) on marine mammals remains limited, it seems reasonable to assume that reducing an animal's ability to gather information about its environment and to communicate with other members of its species would be stressful for animals that use hearing as their primary sensory mechanism. Therefore, NMFS assumes that acoustic exposures sufficient to trigger onset PTS or TTS would be accompanied by physiological stress responses because terrestrial animals exhibit those responses under similar conditions (NRC 2003). More importantly, marine mammals might experience stress responses at received levels lower than those necessary to trigger onset TTS. Based on empirical studies of the time required to recover from stress responses (Moberg 2000), NMFS also assumes that stress responses could persist beyond the time interval required for animals to recover from TTS and might result in pathological and pre-pathological states that would be as significant as behavioral responses to TTS.

There is little information available on sound-induced stress in marine mammals or on its potential to affect the long-term health or reproductive success of marine mammals (Fair and Becker 2000, Hildebrand 2005, Wright et al. 2007a, 2007b). Potential long-term effects, if they occur, would be mainly associated with chronic noise exposure (Nieukirk et al. 2009). As noted above, exposure to low-frequency ship noise, particularly in heavy ship traffic areas, may be associated with chronic stress in whales - Rolland et al. (2012) suggest evidence of a reduction in stress hormone levels associated with reduced exposure of North Atlantic right whales to noise from large commercial vessels. Disruption in feeding, especially within small populations could have impacts on whales, their reproductive success and even the survival of the species (NRC 2005).

Available data on potential stress-related impacts of anthropogenic noise on marine mammals are extremely limited; research on the stress responses of marine mammals and the technologies for measuring hormonal, neuroendocrinological, cardiological, and biochemical indicators of stress in marine mammals are in the early stages of development (ONR 2009). Obtaining samples from free-ranging marine mammals is complicated by the brief periods of time most are visible while either hauled-out or at the surface to breath, by home ranges that may include expansive and inaccessible areas of ocean which limits the potential for continued or repeated monitoring, and many species cannot be easily captured or sampled using traditional methods (ONR 2009). Blood sampling is not currently possible for large, free-swimming whales. Conducting stress research on marine mammals, therefore, requires novel approaches to obtaining physiologic data and samples. Real time measurement of existing stress hormones and biomarkers are further limited by the invasive nature of many of the sampling methods (e.g., chase, restraint), which may, themselves, be stressors that could mask the physiological signal of interest (ONR 2009).

Although extensive terrestrial vertebrate datasets illustrate that the impacts of chronic stress effects can adversely impact individuals through immune suppression, inhibition of other hormonal systems, and the disruption of reproductive function, such studies within marine systems remain rare. Laboratory studies showing explicit stress responses to noise and field noise measurements have increased our ability to compare hormone levels with other potentially causative variables. However, there are no large cross-sectional datasets of stress markers in free-ranging marine populations, which means that we lack an understanding of natural variation within individuals based on sex, age, and reproductive status. Further, we do not fully understand the relationship among various hormones and the quantitative differences that may be expected among sample types (e.g., blood, blubber, feces) in free-ranging individuals. Therefore, there is a current inability to interpret context and the biological significance of variation in stress markers in individuals. Pursuant to NEPA, the full quantitative suite of this information is considered unavailable, however, the absence of this particular information does not inhibit our ability to evaluate the reasonably foreseeable significant adverse impacts on the human environment. The summary above of the available data related to stress effects, combined with the more complete data available regarding the more primary

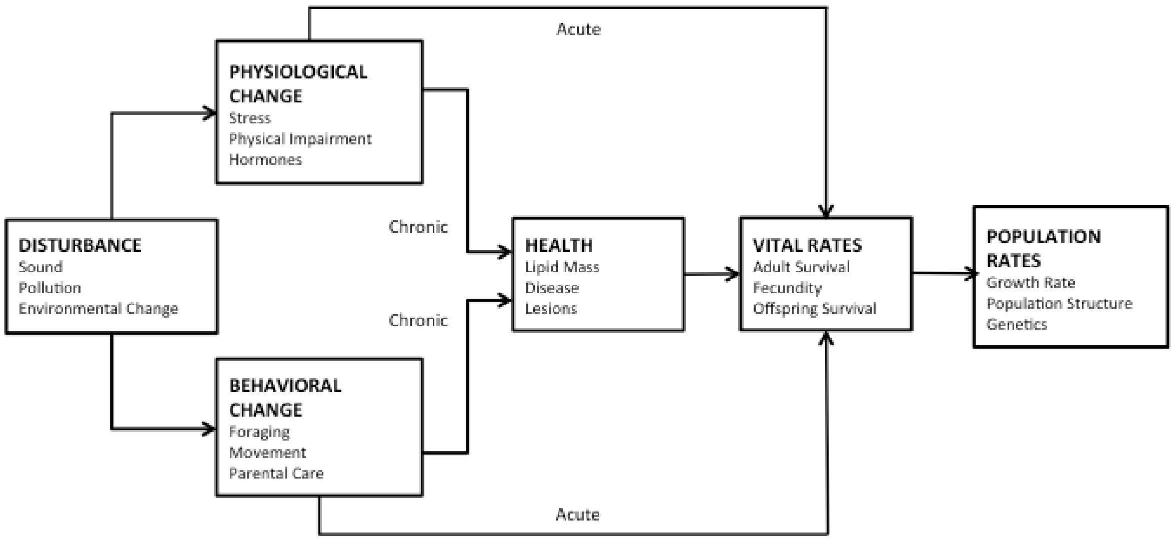
direct effects of behavioral disturbance from industry activities allow us to reasonably assess the effects of these activities on marine mammals.

Recent novel, non-invasive approaches developed for collecting corticosteroid and hormone samples from free-swimming large whales include fecal sampling (Hunt et al. 2006) and sampling whale blows (Hogg et al. 2009, NEA 2011). Both techniques have been used to collect samples from North Atlantic right whales (*Eubalaena glacialis*) and show promise. The former, however, is limited by the frequency with which feces are encountered. Methods for sampling whale blows, obtaining sufficiently large samples, and measuring stress hormones were being developed and tested by the New England Aquarium during 2011 (NEA 2011). These methods are still being developed and their practicability and viability have not been tested on Arctic species.

Linking Disturbance and Sub-lethal Effects to Population Level Effects

Because of the methodological challenges (including difficulty identifying all of the contributing variables), as well as the time and resource commitment necessary, few studies have quantified the ultimate impacts to marine mammal populations associated with disturbance from noise or other causes. Lusseau and Bejder (2007) present data from three long-term studies illustrating the connections between disturbance from whale-watching boats and population-level effects in cetaceans. Across these three multi-year studies, the effects of increased boat traffic from tourism ranged from a 15% decrease in abundance (Shark Bay Australia, bottlenose dolphins, Bejder et al., 2006), a transition from a short-term avoidance strategy to long-term displacement resulting in reduced reproductive success and increased stillbirths (Fiordland New Zealand, bottlenose dolphins, Lusseau 2004), to decreased foraging opportunities and increased traveling time that a simple bioenergetics model equated to decreased energy intake of 18% and increased energy output of 3-4% (Vancouver Island Canada, northern resident killer whale, Williams et al., 2006). These studies are presented because of the lack of similar studies for other activity types, not because of an enhanced concern for whale watching above other activity types. In fact, Weinrich and Corbell (2009) report that the reproductive success of female humpback whales was not affected by whale watching exposures in southern New England.

In order to understand how the effects of activities to individual marine animals may or may not impact stocks and populations, it is necessary to understand not only what the likely disturbances are going to be, but how those disturbances or other impacts may affect the reproductive success and survivorship of individuals, and then how those impacts to individuals translate to population changes. Following on the earlier work of a committee of the U.S. National Research Council (NRC 2005), New et al. (2014), in an effort termed the Potential Consequences of Disturbance (PCoD), outline an updated conceptual model of the relationships linking disturbance to changes in behavior and physiology, health, vital rates, and population dynamics, as depicted in the flow chart below. While this effort targets marine mammals, this conceptual model is broadly applicable in illustrating the potential pathways from individual disturbances to population-level impacts for other taxa.



Potential Consequences of Disturbance conceptual model of the relationships linking disturbance to changes in behavior and physiology, health, vital rates, and population dynamics (New et al., 2014).

As described in the PCoD model, adverse behavioral and physiological changes resulting from disturbance (stimulus or stressor) can either have acute or chronic pathways of affecting vital rates. For example, acute pathways can include changes in behavior or habitat use, or increased stress levels that directly raise the probability of mother-calf separation or predation. Chronic effects on vital rates occur when behavioral or physiological change has an indirect effect on a vital rate that is mediated through changes in health over a period of time, such as when adverse changes in time/energy budgets affects lipid mass, which then affects vital rates (New et al., 2014). New et al. (2014) outlined this general framework and compiled the relevant literature that supports it. Each box in the flow chart above contains added specific examples of types of behavioral, physiological and biological changes, health effects, vital rates and population rates for which there are data illustrating the connections between these stages of effects for certain species and situations. Further, these authors, and others involved in the PCoD effort, have developed state-space energetic models for four example species (southern elephant seal, North Atlantic right whale, beaked whale, and bottlenose dolphin), that illustrate how specific information about anticipated behavioral changes or reduced resource availability can be used to effectively forecast longer-term, population-level impacts (New et al., 2014; New et al., 2013a; Schick et al., 2013; New et al., 2013b).

Unfortunately, empirical data adequate to quantify the relationship between behavioral or physiological changes and fitness impacts does not exist for the majority of marine mammal species and the existing models are very species- and scenario-specific. However, some inferences regarding the relative importance of certain factors may be appropriate for different species in certain circumstances. Meanwhile, to fill this gap in adequate empirical data, an "interim" version of the PCoD framework has been developed that uses a formal expert elicitation process to estimate parameters (and associated uncertainty) that define how changes in behavior or physiology affect vital rates and incorporate them into a stochastic model. The framework can be used to predict the anthropogenic disturbances on animal populations. King et al. (2015) report on the outcome of the first interim PCoD effort to assess the effects of United Kingdom offshore wind farm construction on harbor porpoises. Similar efforts are currently underway to evaluate the effects of Navy activities on beaked whales and sperm whales in certain areas.

Stranding and Mortality

Causes of strandings and mortality related to sound could include: 1) swimming into shallow water to avoid sound; 2) a change in dive behavior; 3) a physiological change; and 4) tissue damage directly from

sound exposure, such as through acoustically mediated bubble formation and growth or acoustic resonance of tissues. Some of these are unlikely to apply to airgun impulse sounds.

Seismic pulses and mid-frequency sonar signals are quite different, and some mechanisms by which sonar sounds have been hypothesized to affect beaked whales are unlikely to apply to airgun pulses. Sounds produced by airgun arrays are broadband impulses with most of the energy below 1 kHz. Typical military mid-frequency sonar emits non-impulse sounds at frequencies of 2 to 10 kHz, generally with a relatively narrow bandwidth at any one time. A further difference between seismic surveys and naval exercises is that naval exercises can involve sound sources on more than one vessel. Thus, it is not appropriate to assume that there is a direct connection between the effects of military sonar and seismic surveys on marine mammals. However, evidence that sonar signals can, in special circumstances, lead (at least indirectly) to physical damage and mortality (Balcomb and Claridge 2001, NOAA and USN 2001, Jepson et al. 2003, Fernández et al. 2004, 2005, Hildebrand 2005, Cox et al. 2006) suggests that caution is warranted when dealing with exposure of marine mammals to any high-intensity "pulsed" sound.

There is no conclusive evidence of cetacean strandings or deaths at sea as a result of exposure to seismic surveys, but a few cases of strandings in the general area where a seismic survey was ongoing have led to speculation concerning a possible link between seismic surveys and strandings. Suggestions that there was a link between seismic surveys and strandings of humpback whales in Brazil (Engel et al. 2004) were not well founded (IAGC 2004, IWC 2007). In September 2002, there was a stranding of two Cuvier's beaked whales in the Gulf of California, Mexico, when the Lamont-Doherty Earth Observatory vessel *R/V Maurice Ewing* was operating a 20 airgun (8,490 in^3) array in the general area. The link between the stranding and the seismic surveys was inconclusive and not based on any physical evidence (Hogarth 2002, Yoder 2002). A mapping survey using a high-power 12 kHz multi-beam echosounder (MBES) was considered a likely trigger for a highly unusual mass stranding of approximately 100 typically oceanic melon-headed whales (*Peponocephala electra*) in Madagascar in 2008 (Southall et al. 2013). Although the cause is equivocal and other environmental, social, or anthropogenic factors may have facilitated the strandings, the authors determined the MBES the most plausible and likely trigger initiating the stranding response (Southall et al. 2013). While seismic airguns have not been positively associated with strandings, and the sources themselves have different characteristics than those sources that have been found to contribute to the cause of known strandings, some of the hypotheses regarding why animals strand include behaviorally mediated responses in which animals have an adverse behavioral response (which seismic surveys are known to cause) and subsequent secondary behaviors (ascending too fast, swimming into areas that are too shallow, etc) that lead to stranding. However, the species present in the Arctic do not include those deep diving species that have been involved in previous strandings associated with loud manmade sound sources.

4.5.2.4.3 Potential Effects from Other Acoustic Sources Used during Surveys

In addition to a single airgun or airgun arrays, the industry typically uses additional acoustic devices during survey activities, such as single and multi-beam echosounders, sub-bottom profilers, and side scan sonars (many of which operate at frequencies outside of the ranges of best hearing for many baleen whales and some pinnipeds). The majority of these sources is smaller and emits sounds at higher frequencies than airguns. The source levels of these devices range from 180 dB re 1 µPa at 1 m to 250 dB re 1 µPa at 1 m and have frequency ranges from 0.2 kHz to 1,600 kHz. Section 2.3.2 of this EIS describes each of these sound sources, with source levels and frequency ranges, in more detail.

Given the directionality and small beam widths for these sources, marine mammal communications are not anticipated to be masked appreciably. Because of the small beam widths, marine mammals would not be in the direct sound field for more than one to two pulses. Additionally, many of these sources emit sounds at frequencies higher than that used by some marine mammals for hearing and/or vocalizing, especially baleen whales.

Behavioral reactions of free-ranging marine mammals to sonars, echosounders, and other sound sources appear to vary by species and circumstance. Observed reactions have included silencing and dispersal by sperm whales (Watkins et al. 1985) and increased vocalizations and no dispersal by pilot whales (Rendell and Gordon 1999). When a 38 kHz echosounder and a 150 kHz acoustic Doppler current profiler were transmitting during studies in the Eastern Tropical Pacific, baleen whales showed no substantial responses, while spotted and spinner dolphins were detected slightly more often and beaked whales less often during visual surveys (Gerrodette and Pettis 2005). Very few data are available on the reactions of pinnipeds to echosounder sounds at frequencies similar to those used during seismic operations. Hastie and Janik (2007) conducted a series of behavioral response tests on two captive gray seals to determine their reactions to underwater operation of a 375 kHz multibeam imaging echosounder that included significant signal components down to 6 kHz. Results indicated that the two seals reacted to the signal by significantly increasing their dive durations. It was determined that the frequencies produced by some sources such as sub-bottom profilers were too high to create TTS and/or PTS among pinnipeds or most cetaceans expected to occur in the area. However, based on some recent reports (Southall et al. 2013 regarding multi-beam echo sounders), NMFS recognizes that these types of sound sources can sometimes result in behavioral responses that rise to the level of take, although, in most cases the vast majority of the operation of these sources will occur while seismic airguns are also operating, which means that the animals in the vicinity of the airgun will already be projected to be taken. At any rate, NMFS will evaluate the potential effects of these source types when analyzing MMPA requests that include the use of such equipment.

4.5.2.4.4 Potential Effects of On-ice Seismic Surveys

Because these activities occur during the winter and early spring months over the ice, no impacts to cetaceans are anticipated, as cetaceans are typically not present in the Beaufort Sea during this time period. Impacts to pinnipeds could potentially occur when they are hauled out on the ice or inside subnivean lairs. Disturbance from noise produced by the seismic survey equipment is expected to include localized displacement from lairs by the seals in proximity (within 150 m [492 ft]) to seismic lines (Kelly et al. 1988). Impacts would only occur to pinnipeds in the Beaufort Sea, as no such surveys are expected to occur in the Chukchi Sea. See Sections 4.5.2.4.10 through 4.5.2.4.15 for details regarding potential effects on bowhead whales, beluga whales, other cetaceans, pinnipeds, walruses, and polar bears, respectively.

4.5.2.4.5 Potential Effects of Aircraft Activities

Potential effects to marine mammals from aircraft activity could involve both acoustic and non-acoustic effects. It is uncertain if the animals react to the sound of the aircraft or to its physical presence flying overhead. Minor and short-term behavioral responses of cetaceans to helicopters have been documented in several locations, including the Beaufort Sea (Richardson et al. 1985a, b, Patenaude et al. 2002). Reactions of hauled out pinnipeds to aircraft flying overhead have been noted, such as looking up at the aircraft, moving on the ice or land, entering a breathing hole or crack in the ice, or entering the water (Born et al. 1999, Blackwell et al. 2004a). Reactions depend on several factors including the animal's behavioral state, activity, group size, habitat, and flight pattern (Richardson et al. 1995). Additionally, a study conducted by Born et al. (1999) found that wind chill was also a factor in level of response of ringed seals hauled out on ice, as well as time of day and relative wind direction. Marine mammal reactions to helicopter disturbance are difficult to predict and may range from no reaction to minor course changes or, occasionally, leaving the immediate area of the activity. Currently, NMFS' threshold for determining if an aircraft overflight may take a marine mammal or not is 1,000 ft. altitude (except for takeoffs, landings, and emergency situations).

4.5.2.4.6 Potential Effects of Icebreaking and Ice Management Activities

Icebreakers produce more noise while breaking ice than when transiting open waters primarily because of the sounds of propeller cavitation (Richardson et al. 1995). Icebreakers typically ram into heavy ice until losing momentum, then back off to build momentum before ramming again. The highest noise levels usually occur while backing full astern in preparation to ram forward through the ice. Overall, the noise generated by an icebreaker pushing ice is typically 10 to 15 dB greater than the noise produced by the ship underway in open water (Richardson et al. 1995). Roth and Schmidt (2010) noted a source level of 200 dB re 1 μPa at 1 m during backing and ramming of ice. Industry in-ice seismic surveys recently conducted in the U.S. Arctic did not employ the "backing and ramming" approach described above but rather required continuous forward progress at 3-4 knots in mostly newly forming juvenile first year ice or young first year ice less than 0.5 m (1.6 ft) thick instead of in thick, multi-year ice (ION 2012). Sounds generated by the icebreaker moving through relatively light ice conditions are expected to be far below the high sound levels often attributed to "backing and ramming" icebreaking in very heavy ice conditions, which are created by cavitation of the propellers as the vessel is slowed by the ice or reverses direction (Erbe and Farmer 1998, Roth and Schmidt 2010). Icebreaking is considered by NMFS to be a continuous sound. Haley et al. (2010a) estimated that as the icebreaker travels through the ice, a swath 3,500 m (2.17 mi) wide would be subject to sound levels ≥120 dB, based on the source level of 185 dB attenuating to 120 dB in about 1,750 m (1.09 mi).

Icebreaking activities may also have non-acoustic effects such as the potential for causing injury, ice entrapment of animals that follow the ship, and disruption of ice habitat (reviewed in Richardson et al. 1989:315). Ice management activities may also have similar effects when moving ice floes away from drill rigs. The species of marine mammals that may be present and the nature of icebreaker activities are strongly influenced by ice type. Some species are more common in loose ice near the margins of heavy pack ice while others appear to prefer heavy pack ice. Propeller cavitation noise of icebreaking ships in loose ice is likely similar to that in open water while noise is expected to be much greater in areas of heavier pack ice or thick landfast ice where ship speed will be reduced, power levels will be higher, and there will be greater propeller cavitation (Richardson et al. 1995).

There is little information available about the effect on marine mammals of the increased sound levels due to icebreaking, although beluga whales have been documented swimming rapidly away from ships and icebreakers in the Canadian high Arctic (Richardson et al. 1995). Little information is available regarding the effects of icebreaking ships on baleen whales, but a similar behavioral response would be expected as those mentioned above. Whales could be diverted or could rapidly swim away from the source. Please refer to Sections 4.5.2.4.10 through 4.5.2.4.15 for details regarding potential effects on bowhead whales, beluga whales, other cetaceans, pinnipeds, walruses, and polar bears, respectively.

4.5.2.4.7 Potential Effects of Vessel Activity

Reactions of marine mammals to vessels often include changes in general activity (e.g., from resting or feeding to active avoidance), changes in surfacing-respiration-dive cycles, and changes in speed and direction of movement. In heavily trafficked areas, vessel noise may induce stress and mask communication in whales (Hatch et al. 2012, Rolland et al. 2012). Past experiences of the animals with vessels are important in determining the degree and type of response elicited from an animal-vessel encounter. Whale reactions to slow-moving vessels are less dramatic than their reactions to faster and/or erratic vessel movements. Some species have been noted to tolerate slow-moving vessels within several hundred meters, especially when the vessel is not directed toward the animal and when there are no sudden changes in direction or engine speed (Wartzok et al. 1989, Richardson et al. 1995, Heide-Jorgensen et al. 2003). Few authors have specifically described the responses of pinnipeds to boats, and most of the available information on reactions to boats concerns pinnipeds hauled out on land or ice. In places where boat traffic is heavy, there have been cases where seals have habituated to vessel disturbance (Bonner 1982, Jansen et al. 2006).

Collisions with seismic or support vessels are possible but highly unlikely. Ship strikes with marine mammals can lead to death by massive trauma, hemorrhaging, broken bones, or propeller wounds (Knowlton and Kraus 2001). Massive propeller wounds can be immediately fatal. If more superficial, whales may be able to survive the collisions (Silber et al. 2009). Vessel speed is a key factor in determining the frequency and severity of ship strikes, with the potential for collision increasing at ship speeds of 15 kn and greater (Laist et al. 2001, Vanderlaan and Taggart 2007).

Incidence of injury caused by vessel collisions appears to be low in the Arctic. Less than 1 percent of bowhead whales have scars indicative of vessel collision. This could be due to either collisions resulting in death (and not accounted for) or a low incidence of co-occurrence of ships and bowhead whales (George et al. 1994).

4.5.2.4.8 Potential Effects of Exploratory Drilling

Exploratory drilling could affect marine mammals through noise, discharge of drilling waste, and accidental discharges such as oil spills. Sounds from exploratory drilling are different from airgun sounds. As described in Section 4.5.1.4 (Acoustics), most drilling sounds from vessels produce sounds at relatively low frequencies below 600 Hz with tones up to around 1,850 Hz (Greene 1987). The potential effects of noise from drilling operations are very similar to airguns, although at a lesser magnitude because source levels of drilling units are not as high as airgun arrays.

Exploratory drilling operations may involve the discharge of drill cuttings and drilling fluids directly into the ocean. As described in Section 4.5.1.5 (Water Quality) these discharges could result in elevated concentrations of metals such as chromium, copper, mercury, lead, and zinc, as well as increased concentrations of hydrocarbons and other organic compounds in the water. Some of the discharge streams that may be permitted for oil and gas activities in the proposed action area have been associated with impacts to marine resources, yet, despite a considerable amount of investment in research of exposures of marine mammals to organochlorines or other toxins, there have been no marine mammal deaths in the wild that can be conclusively linked to the direct exposure to such substances (O'Shea 1999). However, the impact of drill cuttings and drilling mud discharges would be local and temporary. Discharged drilling fluid should be well diluted within 100 m (330 ft) so that any impacts would be local and temporary, assuming that whales continue to swim through and past the discharge plume. If toxic contaminants are present in discharges, only a small area of potential habitat and prey base for marine mammals might be contaminated.

Many of the contaminants of concern, including organic contaminants such as organochlorine compounds and PAHs, as well as metals such as chromium and mercury, have the potential to accumulate in marine mammals. Indirect effects to marine mammals could result from exposure to contaminants of concern through the food web and the relevant pathway of exposure would involve trophic transfers of contaminants rather than direct exposure. Monitoring conducted as part of the ANIMIDA and cANIMIDA projects has shown that oil and gas developments in the Alaskan Beaufort Sea "are not contributing ecologically important amounts of petroleum hydrocarbons and metals to the near-shore marine food web of the area" (Neff 2010). Additional mitigation measures C3, C4, and C5 include requirements to ensure reduced discharge of the specific discharge streams identified with potential impacts to marine mammals or marine habitat. Those discharge streams include drill cuttings, drilling fluids, sanitary waste, domestic waste, ballast water, and bilge water. Elimination or reduction of those discharge streams is expected to reduce the potential for adverse impacts to marine mammals. Additional mitigation measures requiring operators to recycle drilling muds may also reduce the potential for adverse impacts to marine mammals and other organisms within the EIS project area.

Accidental discharges of oil or other contaminants could also occur during exploratory drilling and would likely adversely affect marine mammals. Standard mitigation measures requiring operators to have plans in place to minimize the likelihood of a spill would reduce the potential for adverse impacts from such

discharges. The effects of a very large oil spill on marine mammals are analyzed in Sections 4.10.6.11 and 4.10.7.11.

4.5.2.4.9 Chronic and Aggregate Effects on Acoustic Habitat

In addition to predicting numbers of marine mammals taken by the individual sound sources proposed for use in each alternative (4.2.6), tables 4.5-14(a-c) specifically consider the total surface area ensonified above noise threshold levels corresponding with potential behavioral disturbance effects that could result in take. Other effects on marine mammals or other species, such as masking of conspecific or other important acoustic cues occurs when anthropogenic noise levels begin to exceed ambient noise levels – generally well below the levels corresponding with take. To get a very broad sense of how this might occur in this action, the total surface area ensonified above 120 was included above in Tables 4.5-14 (a-c). While low-level masking may not have an immediate impact, if it occurs for extended periods it has the potential to decrease the value of habitat and can lead to consequent chronic effects.

All of the sound present in a particular location and time, considered as a whole, comprises a "soundscape" (Pijanowski et al., 2011). When examined from the perspective of the animals experiencing it, a soundscape may also be referred to as "acoustic habitat" (Clark et al., 2009, Moore et al., 2012a, Merchant et al., 2015). Higher background noise levels, chronically sustained over time, limit the ability of marine species to detect and interpret important acoustic cues. Through the process of developing this FEIS, commenters recommended that NMFS include a mechanism for better assessing the chronic and aggregate effects of the Alternatives explored in this EIS. Below are the results of a first-order assessment to do so. The complete report is attached as Appendix F (Cumulative and Chronic Effects in the Arctic), and excerpts of the results are included below and are referenced elsewhere in the document, both in relation to changes in the acoustic environment and in potential impacts on marine mammal species. Additional public review (via the MMPA incidental take authorization process) and potentially peer review, of the methods, assumptions, and possible interpretations included in this approach will be solicited in order to ensure appropriate consideration and application of this analysis in a management context. Because this novel analytical exercise was conducted specifically for the purposes of this EIS and has not been published previously, it is presented here formatted similar to that of a journal article, including more detail than other EIS sections to ensure the reader is able to obtain the necessary information to fully understand this exercise without the need to consult appendices or other references.

Abstract

Effective detection of sounds is critical for aquatic animals, and methods are needed to assess and minimize the longer-term and aggregate effects of noise on marine species and their habitat, in addition to acute impacts at closer range. Here, we present the results of a first-order assessment of the chronic and cumulative effects of noise produced by oil and gas exploration activities in the Beaufort and Chukchi Seas. Modeling was conducted for a 3.5-month period (July through mid-October) for 10 locations (receiver sites) of biological importance and for six scenarios corresponding to alternatives in this EIS, including: all three levels of exploration activity (Alternatives 2, 3, and 4) and both with and without proposed time/area closures at each of these activity levels. "Lost listening area" was calculated among scenarios and relative to a baseline ambient noise estimate and considering the hearing sensitivity of low and mid-frequency cetaceans. "Lost communication space" was calculated among scenarios and relative to ambient estimates for a 1/3 octave band representing dominant frequencies of bowhead whale vocalizations. Results are reported as remaining listening area or communication space for a maximum of two depths (5 and 30 m) at each of the 10 locations.

Broadly, results for all three activity levels indicate substantial losses in listening area for both mid- and low frequency species at the three eastern-most sites, with near total loss at the Cross Island site (site 9, >95%), as well as the deeper Beaufort site (site 8, >95%), and significant losses at the Kaktovik site (site 10, >75%). Site 7 (Barrow Canyon) also sustained notable losses across all activity levels but only in

shallow depths (up to 70%). Site 3 incurred little listening area loss at the lowest level of activity, but loss at shallower depths increased notably with higher levels of activity (up to 72%). The remaining areas incurred virtually no lost listening area in any scenario. At the one receiver site located within a closure area that incurred listening area loss at any level (site 7 in Barrow Canyon), virtually no differences were noted in listening area when the closures were applied, which was likely heavily influenced by the method of removing the top 10% closest seismic shots, which is used to ensure that near-field seismic shots do not dominate the measured noise. Communication space did not notably decrease at any site except site 8 (bowhead migration route with cow-calf pairs) at the deeper depth, which suffered 24-28% loss.

There is ample evidence to support the fact that significant reductions in listening area or communication space can negatively affect aquatic animals; however, data are lacking to document links to consequences for long-lived and often wide-ranging species such as marine mammals. In contrast, with estimation of acoustic harassment, this analysis is not designed to evaluate the exposure of individual animals to seismic sources from one moment to the next. Rather, this analysis is intended to ensure consideration of the longer-term and wider-ranging noise effects from these sources and to augment the more traditional analysis of acute effects (injury and behavioral harassment). While these results are broadly informative (especially when considered as a whole across the U.S. Arctic), it is important to remain cognizant of the methods and simplifying assumptions when making location-specific interpretations and comparisons. For example, the distribution in space and time of seismic, drilling, and vessel activity will significantly influence the resulting cumulative noise exposure at a specific location. Here, projected levels were distributed based on informed conceptual examples, but actualized survey activity may result in higher concentrations in some areas and lower in others. The effect of concentrations of activity in high proximity to selected locations will continue to be offset by the methods applied here to remove the closest 10% of pulses in order to focus on long-term accumulation of energy at regional scales. However, this same method can result in an under-representation of the value of closure areas at maintaining listening and communication space. Similarly, the assumption made here that none of the activity that would have occurred in a closure area would be redistributed outside that area must be carefully considered when interpreting results (i.e., applying closures results in increased levels of activity in remaining area outside of closures). NMFS conducted this first-order chronic and cumulative assessment in response to recommendations made during the public comment period on the DEIS and SDEIS, and we are reporting our initial results as they relate to different scenarios addressed across EIS Alternatives.

Introduction

Human-produced underwater noise impacts aquatic animals and ecosystems in complex ways, including through acute, chronic, and cumulative effects. Sound is a fundamental component of the physical and biological habitats that many aquatic animals and ecosystems have evolved to rely on over millions of years. Increases in noise and changes in soundscapes (the sounds heard in a particular location, considered as a whole) can lead to reduced ability to detect and interpret environmental cues that animals use to select mates, find food, maintain group structure and relationships, avoid predators, navigate, and perform other critical life functions. Designing noise management techniques to conserve the quality of acoustic habitat in addition to minimizing more direct adverse physical and behavioral impacts necessitates new decision support tools.

Such tools include evaluation of noise influence over longer time and larger spatial scales appropriate to represent the ecological and human activity contexts in which animals are experiencing noise. Additionally, methods are needed to derive metrics associated with these noise field evaluations that can be used to estimate their biological consequences for animals. For example, “loss of communication space” estimates the area over which a specific animal signal, used to communicate with conspecifics in biologically-important contexts (e.g., foraging, mating) can be heard, in noisier relative to quieter conditions (Clark et al. 2009). “Lost listening area” similarly estimates the more generalized contraction of the range over which animals would be able to detect a variety of signals of biological importance,

including eavesdropping on predators and prey (Barber et al. 2009). Such metrics do not, in and of themselves, document fitness consequences for the marine animals that live in chronically noisy environments. Fitness consequences, especially mediated through changes in the ultimate survival and reproductive success of whole populations of animals, rather than just individuals, are notoriously difficult to study, and particularly so underwater. However, it is increasingly well documented that aquatic species rely on qualities of natural "acoustic habitats", with researchers quantifying reduced detection of important ecological cues (reviewed in Francis & Barber 2013), as well as survivorship consequences in several species (Simpson et al. 2014; Nedelec et al. 2015). Application of this growing body of best available science to management decisions will therefore necessitate application of new approaches, as well as increasing investment and collaboration amongst scientists and managers to improve their efficacy and applicability to environmental protection.

Appendix F presents the results of a first-order cumulative and chronic effect assessment for noise produced by oil and gas exploration activities in the U.S. Arctic. Sources associated with these activities that were considered to contribute to cumulative, chronic noise levels in this region during the modeled time period included drillships and support vessels and four different types of airgun arrays. Vessel noise, mainly from propellers, is well documented to contribute to, and often dominate, background noise levels in regions where traffic is regular or during time periods where it is omnipresent (Urick 1983). Direct exposure to the intense pulses produced by airguns can result in acute impacts at close ranges. However, in addition, low-frequency dominant seismic airgun noise undergoes multiple reflections at the ocean bottom and surface and refraction through the water column sediment, causing prolonged decay time of the original acoustic signals (Urick 1984). Extended decay time can lead to high sound levels lasting from one impulse to the onset of the next, elevating ambient noise levels (Guan et al. 2015). In addition, low frequency energy from airgun surveys, with access to conducive propagation conditions (e.g., deeper waters), has been documented to travel long distances, contributing to background noise over very large areas. Seismic survey noise has been documented up to 3000 - 4000 km away as the loudest component of underwater ambient noise (Nieukirk et al. 2004, Nieukirk et al. 2012) and can raise background noise levels by 20 dB over 300,000 km^2 continuously for days (International Whaling Commission 2005). Baleen whales, including bowhead whales, produce calls that span a low frequency range that overlaps noise produced by airguns (Richardson et al. 1995), and presumably their best hearing abilities fall in this range as well (20 Hz-30 kHz) (reviewed in Ketten et al. 2013). Implications for acoustic masking and reduced communication space resulting from noise produced by airguns surveys and vessels are thus expected to be heightened for baleen whales.

Methods and Results

Appendix F presents details of the methodology applied in this study, including maps of key spatial attributes, and includes tables of all results. Key aspects of methods and results are summarized here, but for significant details and points of clarification, we refer the reader to the Appendix.

Acoustic modeling was conducted for 10 locations, (Table 4.5-19a), termed receiver sites, within the study area to examine cumulative noise produced by four exploration alternatives (Table 4.5-19b). The locations of the receiver sites are given in Table 4.5-19a and shown in the map of Figure 4.4. These sites were chosen to reflect areas of biological interest or diversity, such as important reproduction, feeding, and migrating areas, as well as subsistence hunting areas.

Table 4.5-19a. Modeled receiver site locations and water depths.

Site	Receiver Site	Latitude	Longitude	Water Depth (m)
1	West of Cape Lisburne	68.62	−167.91	51.16
2	Point Lay	69.82	−163.37	19.43
3	Chukchi leases	71.13	−162.43	44.26
4	Hanna Shoal	72.15	−163.33	32.02
5	Point Franklin	70.96	−159.62	54.54
6	Peard Bay	71.26	−157.30	54.60
7	East of Barrow	71.52	−154.85	31.23
8	Beaufort Sea shelf slope	71.54	−150.31	1853.82
9	Cross Island	70.56	−147.90	9.43
10	Kaktovik	70.28	−143.69	40.43

The activity level alternatives considered here are the same as those addressed in the remainder of this FEIS. These include a no-activity alternative (Alternative 1) and three activity levels (Alternatives 2-4) of increasing seismic and exploratory drilling activities. The number and type of activities in the Beaufort and Chukchi Seas for Alternatives 2-4 are presented in Table 4.5-19b. Two scenarios were considered for each Alternative. The first scenario assumed no closure areas/times. The second scenario excluded (but did not displace) activities or sections of surveys that would result in sound levels of ≥ 160 dB re 1 µPa (rms SPL) within the closure areas of Barrow Canyon, Hanna Shoal, Kasegaluk Lagoon, Ledyard Bay, Cross Island, and Kaktovik. For each Alternative, exemplar locations of activities were chosen. The location of the activities is shown for each Alternative and scenario in Figures 2-7 of Appendix F. Of important note, the number and distribution of activities modeled for each Alternative were based on the conceptual examples described in Section 4.2.5 of the EIS and illustrated in Figures 4.7 to 4.9 and 4.15 to 4.17, not on the maximum possible number of activities. The grey lines shown in these maps outside the closure areas indicate the extended zone required to keep root mean square (rms) seismic sound levels below 160 dB re 1 µPa at the closure area boundaries.

Table 4.5-19b. Number of modeled activities associated with each alternative in each sea.

Activity	Alternative 2		Alternative 3		Alternative 4	
	Beaufort	Chukchi	Beaufort	Chukchi	Beaufort	Chukchi
2D/3D seismic survey (4500/3200 in^3 airgun array)	1	1	2	2	4	4
3D ocean bottom cable/node survey (640 in^3 airgun array)	1	-	2	-	2	-
Shallow hazard survey (40 in^3 airgun array)	1	1	2	3	3	4
Exploration drilling (Mobile Offshore Drilling Unit with fleet of 8–12 support vessels)	1	1	2	2	4	4

Representative acoustic source types were specified for each activity type, with selected airgun array sizes used for seismic exploration representative of those used in the Arctic since 2006 (see Appendix F). The acoustic fields around the receiver sites were modeled at frequencies from 10 Hz to 5 kHz, up to a range of 500 km. Results are provided for two receiver depths: 5 and 30 m.

Cumulative SELs and time-averaged equivalent sound pressure levels (L_{eq}) at the selected receiver sites were calculated resulting from all shots from seismic surveys and exploratory drilling activities (which include support vessels), as specified for each Alternative. The accumulation period was three and a half months, from 15 July to 31 October, representing the duration of concentrated activity evaluated in the FEIS. A feature of underwater sound propagation is that nearby sources contribute substantially more SEL than more distant sources, since the exposure levels decay with the square of distance from the source. This causes cumulative SEL received from spatially distributed and moving sources to be dominated by the sources closest to a receiver. However, the duration of exposures from very close sources is typically quite short. While exposures from nearby sources are important for assessing acute effects, their inclusion in a chronic effects assessment can be misleading. To overcome this issue, this approach excluded the highest seismic shot exposures received during a fraction (10%) of the total study time period. No drilling noise was excluded, as it was assumed to remain constant for the full duration of the study period.

Marine mammal hearing frequency weighting filter coefficients were applied to the received levels, and results are presented both with and without weighting. Filters for Low-Frequency Cetacean (LFC) and Mid-Frequency Cetacean (MFC) were used, as defined by Southall et al. (2007). Results of cumulative SEL (Tables 4-6) and L_{eq} (Tables 7, 9 and 11) calculations are presented in Appendix F.

To prepare to estimate lost listening area and changes in communication space for various levels of seismic and exploratory drilling activities, a baseline ambient noise level was assumed. In this study, ambient noise levels were estimated using mean (50th percentile) ambient levels recorded in the Chukchi Sea over the 2014 open-water season. Ambient levels in the Beaufort Sea were also estimated based on those of the Chukchi Sea. Broadband ambient levels (10–5000 Hz) varied between 98.9 and 105.7 dB re 1 μPa, depending on the receiver location. Ambient levels for the 1/3 octave centered at 160Hz ranged between 86.2–91.9 dB re 1 μPa across sites. Mean ambient spectra were assigned to each receiver site based on proximity to the actual recorder sites where ambient noise was measured and on the similarity in water depth between the recorded and modeled receiver sites. Tables 8, 10 and 12 present modeled L_{eq} ***above ambient*** at each receiver site with M-weighting for low- (LFC) and mid-frequency cetaceans (MFC) and without weighting.

The lost listening area assessment method has been applied to in-air noise (Barber et al. 2009) and in National Park soundscape management contexts (NPS 2010). The term "listening area" refers to the region of ocean over which sources of sound can be detected by an animal at the center of the space. Sound sources considered by this method can be the same species (as discussed below for communication space), a different species (e.g., a predator or prey species), natural sounds (such as shifting ice), or anthropogenic sounds. The lost listening area method applied by Barber et al. (2009) calculates a fractional reduction in listening area due to the addition of anthropogenic noise to ambient noise. It does not provide absolute areas or volumes of space; however, a benefit of the lost listening area method is that it does not rely on source levels of the sounds of interest. Instead, the method depends on the rate of sound transmission loss. Such results can be considered with frequency weightings, which represent the hearing sensitivity variations of two marine mammal species groups and transmission loss variations with range, or more generally without weighting. Results are presented as ***a percentage of the original listening area remaining***, due to the increase in noise levels under each Alternative and scenario relative to no activity (ambient conditions), and between each Alternative and scenario (Appendix F, Tables 13 to 18).

The communication space assessment was performed using methods previously implemented for examining anthropogenic noise effects on blue, fin and right whales (Clark et al. 2009, Hatch et al. 2012). Communication space estimates the area within which bowhead whales can detect calls[5] from other bowhead whales. All calculations were performed in the single 1/3-octave frequency band centered at 160 Hz. This frequency band had the highest received sound levels for a large number of bowhead whale calls recorded during a multi-year acoustics survey in the northeastern Chukchi Sea. A 1/3-octave band sound level of 156 dB re 1 µPa at 1 m was specified. An estimate of ~15 dB signal processing gain (which accounts for the animal's ability to not only detect but recognize a signal from an animal of the same species) was applied. Noise L_{eq} across sites and Alternatives in the 1/3-octave band centered at 160Hz ranged from 86.2-92.0 dB re 1 µPa, a similar range to ambient. Noise levels at sites 3, 8, 9, and 10 were most often above ambient (depending on the alternative), but still fell within this min-max range. Tables 19-21 present the area (km^2) of communication space at each receiver for the modeled bowhead call under ambient conditions (titled "default") and under each Alternatives and scenario, ***representing lost communication space in both area and percentage***. Tables 22-24 assess relative loss of communication space between the Alternatives.

The results reflect the fact that the locations close to the coast in the Chukchi Sea were relatively distant from the placement of the modeled activities (see Figures 2 through 7 in Appendix F). Effects at these sites (receiver sites 1, 2, 5 and 6) showed little reduction in communication space and listening area, relative to ambient conditions, under any of the Alternatives.

One of the two sites further offshore in the Chukchi, site 4 (Hanna Shoal), showed a negligible (<0.5%) reduction in listening area and no reduction in communication space for any of the Alternatives. Although this site is of key biological interest for walrus and a closure was designed around it, the modeled seismic and drilling activity was some distance from this location.

The other offshore Chukchi site (Site 3) was closer to several of the modeled survey activities. The lowest levels of modeled activity (Alternative 2) did not result in significant lost listening area. However, higher levels of activity (Alternative 4) resulted in an up to 70% reduction of listening area, relative to the area available under ambient conditions. Losses were particularly high for the shallower modeling results (5 meters). Corresponding losses of communication space for bowhead whale calls at this location were less significant, with only 7% of communication space estimated lost under the highest activity levels. Communication space was estimated to be higher for the deeper modeling results at this site (30 meters).

Site 7, east of Barrow (important bowhead whale feeding site), showed more significant impacts from the modeled activities. This site showed decreases in listening area of up to 65% (leaving only 35% of the original area) under the lowest levels of modeled activity (Alternative 2) and up to 70% for Alternative 4. Interestingly, this site did not show corresponding reductions to communication space.

Site 8, which is located in deep water (1854 m) on the edge of the Beaufort Shelf, experienced very large decreases in listening areas due to anthropogenic sound related to exploration activities. Listening areas were reduced up to 98.1% under the lowest modeled activity levels (Alternative 2), leaving as little as 1.9% of the original listening area, due to additions of ~10dB of noise relative to ambient estimates. The corresponding reduction in the listening area for Alternatives 3 and 4 were up to 98.8%. The reductions in bowhead communication space were more significant than for other sites, though still more moderate than listening area losses. Communication space, relative to estimates of ambient, was reduced by up to 19.8% for Alternative 2, 24.2% for Alternative 3 and 26.2% for Alternative 4. The greater sensitivity of this site to exploration activities appears to be due to an upward refracting sound speed profile in the deep water

[5] The term "vocalization" is used here to refer to sounds produced by the vibration of tissues surrounding the blowhole of bowhead whales even though these are not produced by vocal chords.

environment that traps sound from more distant sources in the upper water column. As introduced above, airgun noise can propagate with relatively low transmission loss over large distances.

Site 9, offshore Cross Island, which is important for subsistence hunting of bowheads, also showed substantial reductions in listening areas. Listening area was reduced by up to 98.7% (leaving just 1.3% of the original listening area) for Alternative 2. The reduction was up to 98.8 for Alternatives 3 and 4. These substantial listening area losses were mainly due to the modeled presence of 12 drilling support vessels within 40 km of the receiver site. Resulting received vessel sounds exceeded ambient levels, which were estimated to be quite low in this very shallow area, by more than 10 dB. Reductions to communication space at this site were predicted to be much less than those for listening area; just 1% for all 3 Alternatives.

Site 10, in the Kaktovik whaling area, also showed substantial listening area reductions, but rather small bowhead communication space reductions. The lost listening area was up to 86% for Alternative 2 (leaving only 14% of the Alternative 1 space), up to 92% for Alternative 3, and up to 93% for Alternative 4. The communication space reductions were 0.3% for Alternative 2, 0.4% for Alternative 3, and 0.6% for Alternative 4.

Discussion

The goal of this analysis was to apply new analytical techniques to support assessment of the biological relevance of noise associated with the FEIS' Alternative levels of oil and gas exploration activity the Beaufort and Chukchi Seas. As stated above, this is considered a first-order analysis, and several simplifying assumptions were necessary. Changes in the distribution of survey and drilling activities would result in differences in the relative amount of noise accumulating at different receiver locations, and that variance was not examined here. Instead, we present results associated with an exemplar distribution of the activity levels examined in the FEIS Alternatives and modification of those distributions to avoid buffered closure areas. Similarly, the approach applied accounts for spatial variance due to factors affecting sound propagation (e.g., topography, bottom type) among the selected locations of documented biological importance to species of key management interest in the region but does not produce results for additional locations (e.g., a uniform map). That said, examination of the key drivers of the results suggest some ability for broader interpretation at other locations.

The metrics reported here (lost listening space and communication space) do not reflect variance in an individual animal's, including an individual bowhead whale's, experience of the noise produced by the modeled activities from one moment to the next. With both sources of noise and animals moving, the time-series of an individual's noise exposure will show considerable variation. The methods applied here are meant to average the conditions generated by introducing low frequency dominant noise sources over a several month period during which animals of key management interest rely on habitats in the study area. It should be noted that this examination is meant to be a companion to additional assessments of the acute effects of the same types of noise sources in the same region; approaches are designed to account for changes in exposure realized by individuals over time, mostly in relatively close proximity to noise sources. Considered as a complement to this, the assessment presented here estimates noise produced by the same sources over much larger spatial scales, and considers how the summation of noise from these sources relates to levels without activity (ambient). Approaches such as the communication space estimation presented here include approximation for the evolved ability of many acoustically active animals, such as bowhead whales, to hear the calls of conspecifics in the presence of some overlapping noise.

The role of ambient noise in setting baselines for evaluation of communication space and listening area loss under different activity levels is central to the interpretation and function of both metrics. Interpretively, both metrics seek to consider the acoustic conditions to which animals have evolved, specifically in places that sustain critical life functions (e.g., feeding, traveling with calves), and estimate degradation in those conditions under various chronically noise-producing scenarios. Ideally, therefore,

selected baselines can approximate background noise conditions in key habitats with little to no intrusion of human-produced noise. It should be noted that such baselines will include sources of at times significant natural noise (e.g., wind and waves). For long-lived animals such as bowhead whales, contemporary noise measurements represent only, at most, a few generations of noise conditions experienced in the Arctic. However, relative to areas with higher levels of noise-producing human activity, contemporary measurements are a reasonable representation of more historical conditions, in the absence of such data. In this case, the mean (50th percentile) level of broadband measurements made during the summer of 2014 in the Chukchi were used to establish baselines. In other regions, lower percentiles would be necessary to account for periodic human-produced noise within measurement data; however, it is believed that such noises were not present in these recordings.

The largest increases in noise levels resulted from transitioning from no activity (Alternative 1 in the FEIS) to any of the remaining Alternatives (2-4). At several locations, increases in cumulative noise levels associated with transitioning among activity levels (e.g., from Alternative 2 to Alternative 3, to Alternative 4) were lower than those associated with adding any level of activity to no activity. In deeper water, at site 8, transitioning from no activity to the lowest level Alternative for activity (2) resulted in an ~ 10 dB increase in noise levels at the site, while further transitioning to the highest level Alternative for activity (4) resulted in ~12 dB over ambient. Relatedly, the highest reductions in listening area and communication space at this and several other sites resulted from adding activity of any Alternative level to no activity. For example, losses of listening area at site 9 were almost complete under the lowest activity Alternative (2) and thus were relatively unchanged by the addition of significant proximate activity under Alternatives 3 and 4. Such findings for these Arctic locations, where ambient noise levels are, in general, lower than expected for areas with higher levels of noise producing activity, support the general assertion that the quietest marine and terrestrial environments are the most vulnerable to noise intrusions, with areas with lower ambient noise levels more easily elevated noise intrusion (Hatch & Fristrup 2009). Such assertions relate to observations that animals in quiet areas are more likely to perceive subtle noise alterations in their environments (Francis & Barber 2013).

That said, there were significant reductions in listening area at some locations resulting from transitioning between lower and higher activity levels (Alternative 2 vs. 4). Given the shallow depths at most of the receiver locations, losses in listening area and communication space resulting from transitioning between Alternatives were strongly influenced by how many of the additional modeled sources were in their proximity (see Appendix F, Figures 2 through 7). Site 10 experienced large reductions in listening area due to the addition of activity at the lowest levels (up to 83% lost) and significant additional loss was estimated in transitioning from Alternative 2 to Alternatives 3 and 4 (42-5%), due to the addition of 3D survey activity directly to the west of this site under Alternatives 3 and 4. Close-proximity vessel noise associated with exploratory drilling had the potential to strongly influence cumulative noise levels at receiver sites, as, in contrast to modeled noise from airgun shots, noise from vessels in very close proximity to receivers was not excluded from this analysis. This is reflected most strongly in the lost listening area calculations for sites 3 and 9, which were located close to concentrations of exploratory drilling support vessels under various Alternatives. At site 3, levels of modeled activity associated with Alternative 2 did not result in significant reductions in listening area relative to ambient and vessels were located at some distance. However, the addition of activity associated with Alternatives 3 and 4 included both the addition 3D airgun array surveys directly to the west and close proximity vessels, and reduced listening area at this site to only 32-33% what was available under Alternative 2. At site 9, close proximity exploratory drilling activity under all Alternatives drove significant listening area reductions estimated at this location.

The effects of closures (Scenario 2) at maintaining communication space or listening area in the presence of increasing activities levels under Alternatives 2 through 4 was relatively low, though notable in a few cases. Site 3, though not inside a closure area, was close to activities that were curtailed by closures surrounding site 4. Area closures resulted in only a 4.2% reduction in communication space (instead of

7% without area closures) at site 3 under Alternative 4. Lost listening area and communication space were consistently slightly less at site 7, which was inside a closure area, when the closure was in effect. The methods used in this assessment to remove 10% of shots from survey activity closest to the receiver locations are likely to have reduced the relative difference between accumulated energy resulting from closures (which further eliminated shots that would have taken place within the 160 dB buffered closure areas). This is especially relevant to interpretation of results at locations 7 and 10, which were nested in closure areas that, under non-closure scenario (1), would have been exposed to very proximate survey activity were it not for the removal of the top 10% of shots. This loss of resolution between closure and non-closure results does not adequately capture the reduction in acute noise exposure that would be experienced by animals within the closure if such mitigation is applied. However, again, the methods of this study focused instead on chronic, longer-term exposure associated with low frequency, well-propagating noise. It is well understood that the size of areas necessary to achieve significant reductions of low frequency chronic noise will vary significantly with local propagation conditions. This study does support the general premise that relatively small closures will be more relevant to reductions in regional-scale chronic noise reduction goals in areas with poorer propagation conditions (e.g., shallower) than in areas with well-propagating noise (e.g., deeper). Finally, this assessment did not evaluate the implications of displacing some or all of the activity that would have taken place within the closure to within the remaining area outside the closure. The FEIS does not estimate whether closures would result in lower activity levels and there was no basis for asserting what portion of activity would be redistributed. The implications of such redistribution on cumulative noise levels both within and outside closures would vary considerably. Some sites inside closures could experience reduced cumulative levels (depending on their size and propagation conditions as noted above) while some sites outside closures could experience higher noise levels due to survey levels displaced to their vicinity.

Comparison between the results between the two metrics applied here highlights important interpretive differences in evaluating the biological implications of higher background noise. The strength of the communication space approach is that it evaluates potential contractions in the transmission of a signal of documented importance to a population of animals of key management interest in the region. In this case, maximum losses of communication space for a calling bowhead whale (28%) were estimated to occur at the deepest water location, off the Beaufort Sea shelf slope (site 8), under the highest activity Alternative (4) with no closures in place (scenario 2). This site is within the Fall bowhead whale migration, when adult females are traveling west with calves and regular communication between them is likely important to maintain group cohesion. Losses were significantly higher at 30 meters depth than at 5 meters depth, reflected the fact that modeled noise within the 1/3 octave band centered at 160Hz were higher at 30 meters than at 5 meters.

Losses of broadband listening area, however, far exceeded losses of communication space evaluated at the same locations and under the same activity levels. This is appropriate to the interpretive role of the lost listening space calculation, which is to provide a more conservative estimate of the areas over which animals have access to a variety of acoustic cues of importance to their survival and reproductive success. It is not understood what all cues used by marine mammals are in the Beaufort and Chukchi, but it is well discussed that acoustics provide particularly important information in areas where other sensory cues are diminished (e.g., dark) and where navigation is challenging (e.g., complex coastlines, topography and ice). Documentation of such cues (reviewed in Barber et al. 2009, Slabbekoorn et al. 2010) indicate that they can be well outside of the frequencies that animals use to communicate with conspecifics, are often of lower source levels that conspecific calls and in many cases cannot benefit from evolved capacity to compensate for noise (e.g., gain applied to communication space calculations), due to the absence of mechanism for natural selection to act (e.g., most eavesdropping contexts). Broadband listening space losses in this study were near complete at sites 8 and 9 in the Beaufort, with maximum losses realized under the highest activity Alternative (4). Again, these areas are important for the Fall bowhead whale migration, with calves, and the shallower area at Site 9 (Cross Island) represents an important bowhead whale subsistence area]. Interestingly, listening area losses were higher at 5 meters depth than at 30

meters depth, reflecting the fact that modeled broadband noise levels were higher at 5 meters than at 30 meters.

Conclusion

This chronic and cumulative effects study is presented to assist the public and managers in further assessing the effects of noise associated with the Alternatives for oil and gas exploration off the coast of Alaska considered in the FEIS. It is meant to ensure treatment of longer-term and wider-range noise effects from sources such as airguns, used in seismic acquisition, to augment more traditional assessment of their acute effects (e.g., auditory injury and harassment). The metrics applied in this first-order study necessitate several simplifying assumptions and do not, in and of themselves, document the consequences of lost listening area or communication space for the survivorship or reproductive success of individual animals, including marine mammals in the Arctic. However, they do translate a growing body of scientific evidence for concern regarding the degradation of the quality of high value acoustic habitats into quantifiable attributes that can be compared among proposed activity levels and distributions and related to the baseline conditions to which animals have evolved.

4.5.2.4.10 Bowhead Whales

This section describes the potential effects of Alternative 2 to bowhead whales. This information is in addition to the information provided in Sections 4.5.2.4.1 through 4.5.2.4.9, which is applicable to marine mammals more generally. Here, we include information specific to bowhead whales.

4.5.2.4.10.1 Direct and Indirect Effects

The primary direct and indirect effects on bowhead whales from activities associated with oil and gas exploration in the Beaufort and Chukchi seas considered under Alternative 2 would result from noise exposure. Ship strikes and habitat degradation are also possible but low probability. Sources of noise include 2D/3D seismic survey equipment (airgun arrays), echosounder and sonar devices associated with site clearance and shallow hazards surveys, support, monitoring and receiving vessels associated with these surveys, icebreaking activities, on-ice vibroseis seismic surveys (Beaufort Sea only), exploratory drilling, and helicopter and fixed wing aircraft associated with the different programs. Details of these activities and associated components can be found in Chapter 2.

Behavioral Disturbance

Anthropogenic noise from oil and gas exploration activities may elicit behavioral responses from bowhead whales. The suite of possible reactions is listed above; known reactions by bowhead whales are included here and described and assessed by region and activity.

Beaufort Sea Activities

2D/3D Seismic Surveys (July through November)

Airgun arrays are the most common source of seismic survey noise. Baleen whales generally avoid operating airguns, but avoidance distances vary by species, locations, behavioral activities, as well as environmental conditions that influence sound propagation (Richardson et al. 1995, Gordon et al. 2004).

Airgun sounds can propagate horizontally for many kilometers (Greene and Richardson 1988). In waters 25 to 50 m (82 to 164 ft) deep, airgun sound can be detected 50 to 75 km (31 to 46 mi) away; in deeper water, ranges can exceed 100 km (62 mi) (Richardson et al. 1995). Ranges from airgun arrays to SPL thresholds between 190 and 120 dB re 1 μPa rms were measured for most seismic surveys and site clearance programs performed with airgun sources in the Alaskan Beaufort and Chukchi Seas between 2006 and 2015 as a component of IHA requirements. A detailed listing of those results is provided in Appendix G and a summary of the average and standard deviations of the 190, 180 and 160 dB re 1 μPa rms distances by source type and environment is given in Table 4.5-11. For example, the average

distances to these threshold levels for surveys on the Beaufort Sea Shelf in >15 m water depth using airgun arrays of 3147 in^3 total volume were: 889 m to 190 dB re 1 μPa, 2573 m to 180 dB re 1 μPa, 11452 m to 160 dB re 1 μPa, and 74813 m to 120 dB re 1 μPa rms.

(Refer to Appendix G for additional details on these measurements.)

Observed responses of bowhead whales to seismic noise vary and may depend on multiple contextual factors, such as whether the whales are feeding or migrating. Feeding bowheads tend to show less avoidance of sound sources than do migrating bowheads. Bowhead whales feeding in the Canadian Beaufort Sea in the 1980s showed no obvious behavioral changes in response to airgun pulses from seismic vessels 6 to 99 km (3.7 to 61.5 mi) away, with received sound levels of 107 to 158 dB rms (Richardson et al. 1986). They did, however, exhibit subtle changes in surfacing–respiration–dive cycles. Seismic vessels approaching within approximately 3 to 7 km (1.9 to 4.3 mi), with received levels of airgun sounds of 152 to 178 dB, usually did not elicit strong avoidance reactions (Richardson et al. 1986, 1995, Ljungblad et al. 1988). Richardson et al. (1986) observed feeding bowheads start to turn away from a 30-airgun array with a source level of 248 dB re 1 μPa at a distance of 7.5 km (4.7 mi) and swim away when the vessel was within about 2 km (1.2 mi); other whales in the area continued feeding until the seismic vessel was within 3 km (1.9 mi). More recent studies have similarly shown greater tolerance of feeding bowhead whales to higher sound levels than migrating whales (Miller et al. 2005, Harris et al. 2007, Koski et al. 2009, Christie et al. 2010). Koski et al. (2008, 2009) observed several groups of bowhead whales that continued feeding near seismic surveys in the central Beaufort Sea in 2007 and 2008 where received sound levels reached between 150 and 180 dB re 1 μPa. Data from an industry aerial monitoring program in the Alaskan Beaufort Sea during 2006 through 2008 and 2010 noted bowhead whale mean distance from the center of active seismic operations increased for traveling but not for feeding whales; however, ice conditions appear to be a factor as well (Funk et al. 2011). This apparent tolerance, however, should not be interpreted to mean that bowheads are unaffected by the noise. Feeding bowheads may be so highly motivated to stay in a productive feeding area that they remain in an area with noise levels that could, with long-term exposure, potentially cause some sort of phyisiological impairment. Koski et al. (2009) noted bowhead whales appear more tolerant of higher levels of seismic noise when there is reason to remain in an area, such as the presence of food. However, other factors likely influence distribution relative to seismic activity, including ice cover, water depth, distance from shore, age, size, breeding status, and other disturbances in the area.

Migrating bowhead whales respond behaviorally more strongly to seismic noise pulses than do feeding whales. Bowhead whales migrating west across the Alaskan Beaufort Sea in autumn showed avoidance out to 20 to 30 km (12.4 to 18.6 mi) from a medium-sized airgun source at received sound levels of around 120 to 130 dB re 1 μPa rms (Miller et al. 1999, Richardson et al. 1999). Avoidance of the area did not last more than 12 to 24 hours after seismic shooting stopped. Deflection might start as far as 35 km (21.7 mi) away and may persist 25 to 40 km (15.6 to 24.9 mi) to as much as 40 to 50 km (24.9 to 31.1 mi) after passing seismic-survey operations (Miller et al. 1999). Analyses of data on traveling bowheads in the Alaskan Beaufort Sea also showed a stronger tendency to avoid operating airguns than was evident for feeding bowheads (Christie et al. 2009, Koski et al. 2009). Richardson et al. (1999) suggests migrating bowheads start to show significant behavioral disturbance from multiple pulses at received levels around 120 dB re 1 μPa. Although travelling whales tend to divert around a sound source at lower sound levels than do feeding whales, some travelling whales appeared to tolerate sounds greater than 120 dB (Koski et al. 2009).

Surfacing, respiration, and diving behaviors of bowhead whales change when exposed to seismic activities (Robertson et al. 2013). Surfacing time decreased, particularly for traveling or socializing non-calf bowheads exposed to seismic sounds. Dive duration was also affected, but effects varied with season (more pronounced in autumn than in summer) and whale activity (e.g., traveling vs. feeding). Traveling whales exposed to seismic operations had the shortest surface times and fewest respirations per surfacing, while feeding whales appeared more tolerant (Robertson et al. 2013).

The effect of seismic airgun pulses on bowhead whale calling behavior has been extensively studied in the Alaskan Beaufort Sea. Recent analyses indicate that calling rates increase when airgun pulses are first detectable above background levels, then level off at nearly double the calling rate in the absence of seismic sounds. Calling rates decrease and the whales become virtually silent at higher received levels from airgun pulses (Blackwell et al. 2015). During the autumn season in 2007 and 2008, calling rates decreased substantially in the presence of airgun pulses (Blackwell et al. 2010a). During August to October 2007, call localization rates (CLRs) dropped substantially at the onset of airgun use at sites near to (median distance 41-45 km) airguns where median received levels from airgun pulses were 116–129 dB re 1 lPa (10–450 Hz). CLRs did not change at distant (median distance >104 km) sites where median received levels were 99–108 dB re 1 lPa (Blackwell et al. 2013). Reanalysis of data from 2007-2010 indicate that call detection rates dropped rapidly when cumulative sound exposure levels (CSELs) were greater than ~127 dB re 1 $\mu Pa^2 \cdot s$ over 10 minutes and whales are nearly silent at received CSELs close to 160 dB (Blackwell et al. 2015). The decrease could be caused by less or no calling by individual whales, deflection of whales around the seismic activity, or a combination of both. Calls resumed near the seismic operations area shortly after operations ended. Aerial surveys showed high sighting rates of feeding, rather than migrating, whales near seismic operations (Blackwell et al. 2010a). In contrast, reduced calling rates during a similar study in 1996 to 1998 were largely attributed to avoidance of the area by whales that were predominantly migrating, not feeding (Miller et al. 1999, Richardson et al. 1999).

The open water season (July through early November) during which proposed seismic activities would occur (for up to 90 days), overlaps with summer feeding and the late-summer/fall westward migration of bowhead whales across the Alaskan Beaufort Sea. Therefore, the potential for exposure and disturbance is high during this time period. Data available from the BWASP and ASAMM surveys and other surveys (Ashjian et al. 2010, Clarke et al. 2011a, 2011b, 2011c, 2012, 2013, Koski and Miller 2009, Moore et al. 2010, Okkonen et al. 2011) reveal areas where concentrations, including feeding aggregations and/or aggregations of females and calves, are more likely to occur in the Beaufort Sea. These areas include a bowhead whale feeding "hotspot" during late summer to fall from Point Barrow to Smith Bay and the Kaktovik area where whales are occasionally observed feeding as early as July, and often occur in higher concentrations beginning in late-August and September.

Seismic activity in the Beaufort Sea would likely impact bowhead whales, although the level of disturbance will depend on whether the whales are feeding or migrating, as well as other factors such as the age of the animal, whether or not it is habituated to the sound, etc. Responses can range from apparent tolerance to interrupted communication, minor displacement, or avoidance of an area. If multiple 2D/3D seismic surveys occurred in areas with concentrations of bowheads present, large numbers of bowheads could potentially be disturbed or potentially excluded by avoidance from feeding habitat for the duration of the survey period. Most observed disturbance reactions appear to be short-term (meaning the length of the exposure to seismic pulses or less time), and short-term reactions to airgun noises are not necessarily indicative of long-term or biologically significant effects. It is not known whether impulsive sounds affect reproductive rate or distribution and habitat use over periods of days or years. The Western Arctic stock of bowhead whales has, however, been increasing at approximately 3.7 percent per year (Givens et al. 2013), during a period of exposure to exploration activities in the Beaufort and Chukchi seas since the late 1960s. In addition, the potential for increased stress, and the long-term effects of stress, are unknown, as research on stress effects in marine mammals is limited (see discussion above). The level of available information is sufficient to support sound scientific judgments and reasoned managerial decisions, even in the absence of additional data of this type.

In terms of the impact criteria of Table 4.5-18, the disturbance effects of exploratory activity under Alternative 2 would be considered of medium intensity. Additionally, contextually, these impacts take place within a known migratory corridor through which these endangered whales must travel with calves and some may be temporarily displaced from preferred feeding areas. The EIS project area encompasses a

large portion of bowhead whale habitat between the Bering Strait and Canadian border, so leaving the area entirely to avoid impacts is not a likely option. The duration of exposures from these surveys, for this Alternative is considered interim because it is limited to the open water season, and any behavioral responses by bowhead whales to activities is expected to be temporary and contained primarily within the time-period that an individual is exposed to the sounds, and because while the impacts are expected to be repeated over multiple years, 3D seismic surveys do not necessarily occur in every year. The extent of the impact will depend on the number of seismic activities and associated support vessels in an area. For individual sound source vessels and likely disturbance effects, impacts are expected to be local. However, where acoustic habitat is concerned, and the potential to mask important acoustic cues, the effects are broader and may be more regional in nature. Bowhead whales are considered unique in context, given both their endangered species status and the important migratory areas in which the impacts occur.

In-ice Seismic Survey (2D/3D) with Icebreaker Support (October to mid-December)

Disturbance effects from seismic activities are anticipated to be the same as described above. The difference with this activity is the additional sound input from icebreaking activities and the extended period of activity into late fall and early winter. The temporal component of this activity and the potential effects of icebreakers are addressed here.

Increased noise from icebreaking activities may present concerns for bowhead whales (NMFS 2010c). Estimated source levels for an icebreaker range from 177 to 191 dB re 1 μPa (Richardson et al. 1995). More recent measurements of the U.S. Coast Guard Cutter Healy found that the sound signature increased approximately 10 dB between 20 Hz and 2kHz when breaking ice (Roth et al. 2013). According to Roth et al. (2013), the highest noise levels resulted while the ship was engaged in backing-and-ramming maneuvers, owing to cavitation when operating the propellers astern or in opposing directions. They found that in frequency bands centered near 10, 50, and 100 Hz, source levels reached 190-200 dB re 1 μPa at 1 m (full octave band) during icebreaking operations. A study by Miles et al. (1987) used models to predict responses of bowhead whales to icebreaker noise and determined that response was likely at distances of 2 to 25 km (1.24 to 15.53 mi). Zones of responsiveness for intermittent sounds, such as an icebreaker pushing ice, were not studied. They further predicted that approximately half of the bowhead whales exhibited avoidance behavior to a traveling icebreaker in open water at 2 to 12 km (1.25 to 7.46 mi) when the sound-to-noise ratio is 30 dB and to an icebreaker pushing ice at a distance of 4.6 to 20 km (2.86 to 12.4 mi) when the sound-to-noise ratio is 30 dB. Migrating bowhead whales avoided an icebreaker-accompanied drillship (with nearly daily icebreaking) by >25 km (>15.5 mi) in 1992 (Brewer et al. 1993).

The additional sound from an icebreaker accompanying seismic activity could cause temporary avoidance of bowhead whales from areas where the vessels are operating and potentially cause temporary deflection of the migration corridor (NMFS 2010c). BWASP and ASAMM surveys flown in September and October of 2006 through 2012 of the Alaskan Beaufort Sea include sightings of bowhead whales through at least mid-October, with sightings occurring from the U.S./Canadian border to Point Barrow (Clarke et al. 2011b, 2011c, 2011d, 2012, 2013). It is during this time period that the likelihood of co-occurrence of bowhead whales and icebreaker-accompanied seismic activity is most probable. Avoidance by bowhead whales of important feeding areas and displacement during migration are possible. The likelihood of interaction diminishes by late October as most bowheads tend to have migrated out of the Beaufort Sea by this time; therefore, impacts to bowhead whales from this type of activity are only anticipated for a short period of time (likely the first few weeks of the survey).

Because in-ice seismic surveys are designed to begin in early to mid-October towards the end of the bowhead whale fall migration westward through the Beaufort Sea, anticipated impacts of in-ice activities would be anticipated to be somewhat lower than those described for 2D/3D seismic surveys above (see Table 4.5-18 for impact criteria definitions). Surveys utilizing icebreakers could, however, cause avoidance and displacement over a larger radius with the additional noise input from the icebreaking

activities, but the period of time over which this activity would overlap with bowhead whales in the Beaufort Sea is much shorter. Based on these factors, anticipated impacts of in-ice activities are anticipated to be of medium intensity, interim duration, local in extent, and would affect a unique resource for any bowhead whales that may occur in vicinity at the beginning of in-ice operations. However, as operations continue, bowheads would no longer occur in the project area, as they overwinter south of the EIS project area.

Ocean-Bottom-Cable or Node Survey (July to October)

An OBC/OBN seismic survey typically covers a smaller area than the streamer surveys discussed above and may spend several days in an area. One such survey is anticipated in the Beaufort Sea under Alternative 2. OBC/OBN surveys may require the use of dual seismic source vessels working in tandem (see Chapter 2, Table 2.4). Noise and disturbance effects of support vessels are discussed separately below.

Reactions to sounds from OBC/OBN surveys are similar to those reported for 2D/3D streamer seismic surveys. A partially-controlled study of the effect of OBC seismic surveys on westward-migrating bowhead whales was conducted in late summer and fall in the Alaskan Beaufort Sea in 1996 to 1998. Whales avoided the sound source out to 20 to 30 km (12.4 to 18.6 mi) at received sound levels of around 120 to 130 dB re 1 μPa rms (Miller et al. 1999, Richardson et al. 1999). Miller et al. (1999) estimated the deflection may have begun about 35 km (22 mi) to the east. Several bowheads moved into the area close to the seismic vessel during periods when airguns were inactive. Avoidance of the area of seismic operations did not persist beyond 12 to 24 hours after seismic shooting stopped.

The open water season of July to October, during which OBC/OBN surveys are likely to occur, coincides with summer feeding and late-summer/fall migration periods for bowhead whales in the Beaufort Sea. Although most bowhead whales feed in the Canadian Beaufort and Amundson Gulf during the summer months, some may occur near Kaktovik as early as July (Koski and Miller 2009). From late-summer through October, bowhead whales commonly occur in nearshore, shallow waters. The median depths of bowhead sightings during 2006 to 2014 BWASP and ASAMM surveys ranged from 19 to 39 m (62 to 128 ft) (Clarke et al. 2015b). In addition, the distance from which migrating bowheads appear to deflect from OBC/OBN sound sources suggest possible disturbance to whales traveling or feeding farther offshore. Moreover, some OBC/OBN surveys occur inside the barrier islands, where bowhead whales are rarely sighted, thus reducing the potential for effects on the animals from these types of surveys.

Anticipated impacts of OBC/OBN surveys, in terms of magnitude (medium), duration (interim), extent (local), and context (unique) would be similar to those described for 2D/3D seismic surveys above. See Table 4.5-18 for impact criteria definitions. Although disturbance effects may extend 20 to 30 km (12.4 to 18.6 mi) from the sound source, with one OBC/OBN survey anticipated in the Beaufort Sea, short-term effects should remain local.

Site Clearance and High Resolution Shallow Hazards Survey Programs (July to November)

High-resolution shallow hazards surveys are of short duration, and the airguns are smaller, generating lower energy sounds and a smaller zone of influence than the larger airgun arrays used for 2D/3D seismic surveys (NMFS 2010b). The radii of ensonification at 120, 160, 180, and 190 dB re 1 μPa rms were calculated for sound sources proposed for use in 2010. Radii calculated for the 40 in^3 airgun were 14,000 m (45,932 ft), 1,220 m (4,003 ft), 125 m (410 ft), and 35 m (115 ft) for the respective sound source levels. Additional information on measured sound radii for such sound sources in the Beaufort and Chukchi seas between 2006 and 2010 is contained in Table 4.5-9. Ensonified zones were not calculated for side scan sonar, single-beam or multi-beam echosounders, or for the bathymetric sonar (NMFS 2010b), as many of these sources are outside the range of best hearing for mysticetes and possibly for other marine mammals. Additionally, as mentioned above, the beam widths of these sources are narrow,

which would only expose marine mammals to the sounds for one or two pulses, at most, if the animal swims in the direct beam width of the source.

Bowheads appear to continue normal behavior when exposed to noise generated by high-resolution seismic surveys. Richardson et al. (1985) tested this by firing a single 40 in^3 airgun at a distance of 2 to 5 km (1.2 to 3.1 mi) from whales. Some bowheads continued feeding, surfacing, diving, or traveling when the airgun began firing 3 to 5 km (1.9 to 3.1 mi) away (received noise levels at least 118 to 133 dB re 1 µPa rms). In other tests, some whales oriented away at 2 to 4.5 km (1.2 to 2.8 mi) and at 0.2 to 1.2 km (0.12 to 0.75 mi) (received noise levels at least 124 to 131 and 124 to 134 dB, respectively). Turning, diving, surfacing, respiration and calling were similar with or without airguns (Richardson et al. 1985a, b).

Site clearance and high resolution shallow hazards surveys on active leases in the Beaufort Sea could overlap spatially and temporally with feeding bowhead whales in some years from Harrison Bay to Camden Bay, particularly during their fall migration from the eastern Beaufort Sea to the Chukchi Sea.

Based on the criteria defined in Table 4.5-18, anticipated impacts of these surveys, in terms of magnitude (medium), duration (interim), extent (local), and context (unique) would be similar to those described for 2D/3D seismic surveys above.

On-ice Vibroseis Survey (January to May)

The presence of bowhead whales are not likely to overlap with an on-ice vibroseis survey due to their absence from the Beaufort Sea during the winter months. If, however, the activity continues into April and May, it could coincide with the spring migration through the nearshore lead system from the Chukchi Sea into the Beaufort Sea. The migratory pathway of bowheads is more narrowly defined during the spring migration largely due to constraints imposed by ice configurations and leads and fractures. The migration corridor through the Beaufort Sea extends farther offshore than that through the Chukchi Sea (Figure 3.2-6), so migrating whales may be sufficiently distant from noise produced from vibroseis to not be disturbed.

Bowhead whales are sensitive to sound, including on-ice sounds, during the spring migration, as noted by Iñupiat whalers:

> *The whales are very sensitive to noise and water pollution. In the spring whale hunt, the whaling crews are very careful about noise. In my crew, and in other crews I observe, the actual spring whaling is done by rowing small boats, usually made from bearded sealskins. We keep our snow machines well away from the edge of the ice so that the machine sound will not scare the whales* (NMFS 2013).

Exploratory Drilling (July through October)

Exploratory drilling is anticipated to initially occur on active leases offshore of Camden Bay. In addition to a drillship or steel drilling caisson (SDC), there will be additional vessels for support and ice management (potentially as many as 8 to 12 for one drilling operation). Potential impacts from additional vessel traffic will be discussed separately from the effects of the drillship operations (see Associated Vessels and Aircraft below). Multiple sites could be drilled each season with up to three wells being a reasonable number for analysis purposes. This is based on the amount of time needed to drill each individual well and the available amount of time to conduct such operations during the ice free months. See Chapter 2 for details of this activity.

Reactions of bowhead whales to drillship operation noises varies. Whales exhibiting apparently normal behavior were observed several times within 10 to 20 km (6.2 to 12.4 mi) of drillships in the eastern Beaufort Sea, and whales have been sighted within 0.2 to 5 km (0.12 to 3 mi) of drillships (Richardson et al. 1985a, b, Richardson and Malme 1993). Bowheads may, however, avoid drillships and accompanying support vessels at 20 to 30 km (12.4 to 18.6 mi) (MMS 2003). The presence of actively operating

icebreakers in support of drilling operations introduces additional sound into the marine environment and affects responses of whales. In 1992, Brewer et al. (1993) noted that migrating bowhead whales avoided an icebreaker-accompanied drillship by >25 km (>15.5 mi). Richardson et al. (1995) observed avoidance behavior in half of the bowhead whales exposed to 115 dB re 1 µPa rms broadband drillship noises. Reaction levels depended on whale activity, noise characteristics, and the physical situation, similar to that observed with seismic sounds. Richardson and Greene (1995) concluded that the observed playback effects of drilling noise were local and temporary and that effects on distribution, movements, and behavior were not biologically important. Continued long-term monitoring of effects may be needed to better address the issue of biological importance.

Continuous noise emitted from stationary sources, such as drillships, elicits less dramatic behavioral reactions (e.g., changes in swim speed, dive behavior) by bowhead whales than do moving sources, particularly ships (Richardson and Malme 1993). Most observations of bowheads apparently tolerating noise from stationary operations were opportunistic sightings of whales near oil-industry operations; whether more whales would have been present in the absence of those operations is not known. Richardson et al. (1990) performed 12 playback experiments in which bowhead whales in the Alaskan Arctic were exposed to drilling sounds. Whales generally did not respond to exposures in the 100 to 130 dB re 1 µPa rms range, although there was some indication of behavioral changes in several instances.

Some bowheads likely avoid closely approaching drillships by changing their migration speed and direction, making distances at which reactions to drillships occur difficult to determine. In a study by Koski and Johnson (1987), one whale appeared to alter course to stay 23 to 27 km (14.3 to 16.8 mi) from the center of the drilling operation. Migrating whales passed both north and south of the drillship, apparently avoiding the area within 10 km (6.2 mi) of the drillship. No bowheads were detected within 9.5 km (5.9 mi) of the drillship, and few were observed within 15 km (9.3 mi). They concluded westward migrating bowheads appeared to avoid the offshore drilling operation during the fall of 1986, and some may avoid noise from drillships at 20 km (12.4 mi) or more.

Monitoring of the Kuvlum drilling site north of Point Thompson occurred during the 1993 fall bowhead whale migration by Hall et al. (1994). These data were later reanalyzed by Davies (1997) and Schick and Urban (2000). Davies (1997) concurred with Hall et al. (1994) that the whales were not randomly distributed in the study area and that they avoided the area around the drill site at a distance of approximately 20 km (12.4 mi). Hall et al. (1994) noted that the distribution of whales observed in the Kuvlum drilling site is consistent with previous studies (Moore and Reeves 1993), where whales were observed farther offshore in this part of the Beaufort Sea than they were to the east of Barter Island and that it was difficult to separate the effect of the drilling operation from other independent variables, such as water depth. However, Davies (1997) noted whales were closer to shore and in shallower water. Results in Schick and Urban (2000) indicated whales within hearing range of the drillship (<50 km [<31.1 mi]) were distributed farther from the rig than they would be under a random scenario. They concluded the spatial distribution of whales was strongly influenced by the presence of the drillship but lacked data to assess noise levels. Other factors that could influence distribution relative to the drillship were support vessels and icebreakers operating in the vicinity, as well as ice thickness (Schick and Urban 2000). All of these studies noted some level of bowhead whale deflection from active drilling operations.

Bowhead whales, including mothers and calves, may occur in waters west of Kaktovik and near Camden Bay as early as July but more typically from late-August through September (Koski and Miller 2009). It appears to be part of the fall migration corridor. Consequently, there is a high likelihood drilling operations in September or October would coincide with bowhead whales migrating through the area, and would elicit reactions ranging from tolerance (mostly by feeding whales) to displacement and avoidance of the drilling noises.

Based on the impact criteria defined in Table 4.5-18, anticipated impacts of exploratory drilling activities in the Beaufort, in terms of magnitude (medium), duration (interim), extent (local), and context (unique)

would be similar to those described above for seismic surveys. The zone of possible displacement around a drillship would also be influenced by accompanying support vessel and icebreaker activity and their respective working distances from the drillship or rig. Shell analyzed the composite noise footprint of its drillship and support vessels during its 2015 Chukchi Sea drill program. That analysis determined that the composite noise emissions exceeded 120 dB re 1 μPa over an average area of 1264 km^2 (488 mi^2) taken over the duration of its activities. This area represents approximately 0.5% of either the Beaufort or Chukchi EIS areas (Austin and Li 2016).

Associated Vessels and Aircraft

Bowhead whales react to approaching vessels at greater distances than they react to most other activities. Vessel sounds vary by vessel size and type, as well as vessel operating conditions. Vessel sounds measured in the Beaufort Sea since 2007 yielded threshold radii to 120 dB re 1 μPa between 120 m (390 ft) for smaller vessels and 13 km (8.1 mi) for large vessels, with a mean value of 2.3 km (1.4 mi) (LGL Alaska Research Associates, Inc. et al. 2013). Vessel-disturbance experiments in the Canadian Beaufort Sea by Richardson and Malme (1993) showed that most bowheads begin to swim rapidly away when fast moving vessels approach directly. Avoidance usually begins when a rapidly approaching vessel is 1 to 4 km (0.62 to 2.5 mi) away. Whales move away more quickly when approached closer than 2 km (1.2 mi) (Richardson and Malme 1993). A few whales reacted at distances of 5 to 7 km (3.1 to 4.3 mi), while others did not react until the vessel was <1 km (<0.62 mi) away. Received noise levels as low as 84 dB re 1 μPa, or 6 dB above ambient, elicited strong avoidance of an approaching vessel from 4 km (2.5 mi) away. During the experiments, vessel disturbance temporarily disrupted activities, and socializing whales moved apart from one another. Fleeing from a vessel usually stopped soon after the vessel passed, but scattering lasted for a longer time period. Some bowheads returned to their original locations after the vessel disturbance (Richardson and Malme 1993). Bowheads react less dramatically to and appear more tolerant of slow-moving vessels, especially if they do not approach directly. Acoustic monitoring in the vicinity of Northstar (an artificial oil production island in the Alaskan Beaufort Sea) indicated that when transient sounds, such as from boats, increased, bowhead whale calls were significantly shorter (Blackwell et al. 2007). Bowhead calling behavior may be affected by exposures to low levels of seismic survey noise from airguns. A study by Blackwell et al. (2013) found calling rates initially increased when they were exposed to low seismic sound levels, then decreased when the exposure levels continued to increase.

Data are not sufficient to determine demographic responses of bowhead whales to vessels. However, more information of this type is not essential for a reasoned choice among alternatives.

Iñupiat whalers expressed concern over vessel impacts on bowhead whales, noting observed displacement caused by barge activity:

> *Bowhead whales have a different view of how they interact with things. For instance, I want to say, again, I've met with you guys, and I explained when I was a whaling captain in '05 was my first year, I saw 100 -- over 100 whales diverted from one barge, and there was no other whales beyond that for the next 15 miles. So I've seen the activity and the diversion of bowhead whales from industry* (testimony provided by Thomas Napageak, Jr. at Nuiqsut Public Scoping Meeting for this EIS, March 11, 2010).

Data on reactions of bowheads to helicopters are limited. Most bowheads showed no obvious response to helicopter overflights at altitudes above 150 m (500 ft) (Richardson and Malme 1993). Patenaude et al. (2002) found that most reactions by bowhead whales to a Bell 212 helicopter occurred when the helicopter was at altitudes of ≤150 m (500 ft) and lateral distances of ≤250 m (820 ft). Reactions included abrupt dives, short surfacings, and breaching, and, most, if not all, reactions seemed brief. The majority of bowheads, however, showed no obvious reaction to single passes, even at those distances. Data were insufficient to analyze effects of repeated low-altitude passes (Patenaude et al. 2002).

Fixed-wing aircraft flying at low altitude often cause bowheads to dive rapidly. Reactions to circling aircraft may be conspicuous at altitudes <300 m (1,000 ft), uncommon at 460 m (1,500 ft), and generally undetectable at 600 m (2,000 ft). Repeated low-altitude overflights at 150 m (500 ft) during aerial photogrammetry studies of feeding bowheads sometimes elicited abrupt turns and quick dives (Richardson and Malme 1993). Aircraft on a direct course are audible only briefly, and whales are likely to resume their normal behavior within minutes after the plane passes (Richardson and Malme 1993). Only 2.2 percent of bowheads during the spring migration reacted to Twin Otter overflights at altitudes of 60 to 460 m (197 to 1,509 ft) (Patenaude et al. 2002). Reactions diminished with increasing lateral distance and altitude. Most observed reactions by bowheads occurred when the Twin Otter was at altitudes of ≤182 m (597 ft) and lateral distances of ≤250 m (820 ft). There was little, if any, reaction when the aircraft circled at an altitude of 460 m (1,509 ft) and a radius of 1 km (0.62 mi) (Patenaude et al. 2002). The effects from an encounter with aircraft are brief, and the whales generally resume their normal behavior within minutes.

During their study, Patenaude et al. (2002) observed one bowhead whale cow-calf pair during four passes totaling 2.8 hours of the helicopter and two pairs during Twin Otter overflights. All of the helicopter passes were at altitudes of 15 to 30 m (49 to 98 ft). The mother dove both times she was at the surface, and the calf dove once out of the four times it was at the surface. For the cow-calf pair sightings during the Twin Otter overflights, the authors did not note any behaviors specific to those pairs. Rather, the reactions of the cow-calf pairs were lumped with the reactions of other groups that did not consist of calves.

The likelihood of spatial and temporal overlap between support vessels and aircraft with bowhead whales in the Beaufort Sea is high. The degree of overlap and interaction depends on the spatial and temporal distribution of activities and whether they are broadly dispersed or clustered. The greatest potential for helicopter or fixed-wing aircraft to cause adverse effects on bowhead whales is in areas where whales are aggregated, especially if aggregations contain large numbers of cow/calf pairs. Activities, such as exploratory drilling, will utilize multiple support vessels, as well as resupply trips and flights to the dock at Prudhoe Bay (see Chapter 2, Tables 2.2 and 2.4). The number of kilometers transited by seismic and various types of support vessels in the Beaufort Sea in 2006 to 2008 ranged from 9,580 km (5,953 mi) in 2006 to 67,627 km (42,021 mi) in 2008 (Funk et al. 2010). During operations, most source vessel speeds are relatively slow, in the range of 3 to 5 kn, although transit speeds are likely to be much higher. Source vessel transit speeds for 2D/3D seismic surveys are estimated at 8 to 20 kn (refer to Chapter 2 for details). If such activity coincides with aggregations of whales, then disruption is likely.

Most observed disturbance reactions to vessel and aircraft activity appear to be short-term. The longer term effects of repeated vessel interactions over a broad area or in a local area where there are concentrations of whales are unknown. Based on the impact criteria for marine mammals defined in Table 4.5-18, disturbance effects of vessel and aircraft activity would likely be considered of medium intensity since at least some whales would be displaced, but they are not likely to leave the EIS project area entirely. The duration of disturbance is expected to be interim; long-term effects are unknown. The extent of the impact would depend on the number of support vessels in an area, but, for individual activities, impacts are expected to be local. Multiple activities in one area or in several areas across the migratory corridor could result in a broader, regional impact. Bowhead whales are considered unique in context, given both their endangered species status and protection and importance to North Slope communities as a subsistence resource.

Chukchi Sea Activities

<u>2D/3D Surveys (July through November)</u>

Effects of 2D/3D seismic noise on bowhead whales in the Chukchi Sea would likely be similar to those described above for the Beaufort Sea. There may be regional differences in sound propagation and areas of ensonification due to bathymetric and water property differences between the two areas (see

Table 4.5-9, Section 4.5.1.4, Acoustics) that would affect distances at which noise impacts may occur. Differences also exist regionally within the Chukchi Sea OCS. For example, endfire sound level threshold distances for 180, 160, and 120 dB re 1 μPa rms were 1.27 km (0.79 mi), 6.69 km (4.16 mi), and 104.3 km (64.8 mi), respectively, at the Kakapo Prospect and 1.14 km (0.71 mi), 7.15 km (4.44 mi), and 58.4 km (36.3 mi), respectively, at the Burger Prospect (Martin et al. 2010). Additional examples of distances to threshold values for other source types and at other locations are provided in Table 4.5-11.

Most bowhead whales that encounter airgun sounds from seismic operations in the Chukchi Sea would be migrating. At the onset of seismic operations in July, few bowhead whales will likely be in the Chukchi Sea. Whales are occasionally seen feeding during summer in the northeast Chukchi Sea, although those observed in June and July 2009 were in the nearshore waters between Point Franklin and Barrow (Clarke et al. 2011a) with another observed feeding in early July 2012 near Icy Cape (Clarke et al. 2013), well inshore of the federal lease sale areas. In September and October, bowhead whales migrate west from the Beaufort Sea into the Chukchi Sea, and most traverse the lease sale area (Figure 3.2-11). It is during this time that disturbance is most probable. Satellite-tagged bowhead whales were most common in the Chukchi Sea Lease Sale 193 Area in September. In this month, the Lease Area contained 31 percent of the total probability of use for all bowhead whales and the areas with the greatest probability of use were in the northeastern part of the Lease Area. In October, the entrie Lease Area contained 7 percent of the total probability of use for all bowhead whales (Quakenbush et al. 2010a).

As detailed above, migrating bowhead whales in the Beaufort Sea respond to seismic noise pulses at lower received levels than do feeding whales, with avoidance out to 20 to 30 km (12.4 to 18.6 mi) from a medium-sized airgun source at received sound levels of around 120 to 130 dB re 1 μPa rms (Miller et al. 1999, Richardson et al. 1999). The estimated 120 dB re 1 μPa rms sound level threshold distances for seismic operations on the Kakapo and Burger Prospects in the Chukchi Sea were two to three times this distance (Martin et al. 2010). Haley et al. (2010b) found a lower percentage of cetacean sightings near source vessels in the Chukchi Sea, suggesting cetacean avoidance of underwater seismic sound. The small sample size of cetaceans exposed to received sound levels ≥160 dB rms was too small to make strong conclusions. The migration corridor in the Beaufort Sea is more concentrated in a relatively narrow band along the Alaskan coast, whereas the migration through the Chukchi Sea is less defined and spread out over a broader area, providing more area for the whales to migrate through on their way to the overwintering grounds (see Figures 3.2-6 and 3.2-11).

Avoidance at some distance from the sound sources is likely and depends on spatial and temporal overlap with migrating bowhead whales. Operations commencing in July may be complete before the peak of migration in September and October. Surveys starting later in the summer or fall, however, would likely ensonify some portion of the bowhead whale migratory corridor with sound levels known to elicit avoidance responses.

Based on the impact criteria defined in Table 4.5-18, anticipated impacts of these activities, in terms of magnitude (medium), duration (interim), extent (local), and context (unique) would be similar to those described above for the Beaufort Sea. However, impacts are anticipated on a smaller number of animals based on the fact that these activities and bowhead whale migration in the Chukchi Sea would co-occur for a shorter period of time than in the Beaufort Sea.

In-ice Seismic Survey (2D/3D) with Icebreaker Support (October to mid-December)

Disturbance effects on bowhead whales that may occur in the vicinity of in-ice seismic surveys with icebreaker support in the Chukchi Sea would likely be similar to those described above for the Beaufort Sea. In-ice seismic surveys could occur both on- and off-lease.

The additional sound from icebreakers accompanying seismic activity could cause temporary avoidance of bowhead whales from areas where the vessels are operating and potentially cause temporary deflection of the migration corridor (NMFS 2010c). Bowhead whales are migrating into and through the Chukchi

Sea during September and October and typically traverse the Lease Sale 193 area at that time (Clarke et al. 2011a, 2013, Brueggeman et al. 2009, Brueggeman et al. 2010, Quakenbush et al. 2010b). Based on satellite-tag data, most bowheads are along the Chukotka coast by November and December (Quakenbush et al. 2010b), and no bowhead whales have been detected during limited COMIDA aerial surveys in November (Clarke et al. 2011a). Small numbers of bowhead whales have been acoustically detected in the Chukchi Sea until early January during low ice years (Delarue et al. 2009). Migrating bowhead whales and icebreaker-accompanied seismic activity are most likely to co-occur in October. Displacement during migration is possible, though the migratory corridor across the Chukchi Sea is broad and spans approximately 3 degrees of latitude (Quakenbush et al. 2010b).

Anticipated impacts of in-ice activities, in terms of magnitude (medium), duration (interim), extent (local), and context (unique) would be similar to those described for the Beaufort Sea despite the less defined migratory corridor in the Chukchi Sea. However, impacts are anticipated on a smaller number of animals based on the fact that seismic operations and bowhead whale migration would only co-occur for a short period of time at the beginning of operations. If a similar survey were occurring concurrently in the Beaufort Sea, there is a potential for some later migrating bowhead whales to encounter survey activities in both seas. However, there would likely be considerable distance between the two operating programs.

Site Clearance and High Resolution Shallow Hazards Survey Programs (July to November)

Disturbance effects on bowhead whales from site clearance and high resolution shallow hazards surveys in the Chukchi Sea would likely be similar to those described above for the Beaufort Sea.

Bowhead whales would most likely encounter these operations in the Chukchi Sea during fall migration. Few bowhead whales occur in the Chukchi Sea in July and August (Clarke et al. 2011a). In September and October, bowhead whales migrate west from the Beaufort Sea into and across the Chukchi Sea (Figure 3.2-11). Potential disturbance depends on spatial and temporal overlap with migrating bowhead whales. Operations commencing in July may be complete before the peak of migration in September and October. Surveys starting later in the summer or fall, however, would likely ensonify some portion of the bowhead whale migratory corridor, though the ensonified zones for these types of surveys are much smaller than those for the 2D/3D seismic surveys.

Based on the impact criteria defined in Table 4.5-18, anticipated impacts of these activities, in terms of magnitude (medium), duration (interim), extent (local), and context (unique) would be similar to those described for the Beaufort Sea. However, impacts are anticipated on a smaller number of animals based on the fact that these activities and bowhead whale migration in the Chukchi would only co-occur for a short period of time.

Exploratory Drilling (July through October)

Known effects of drilling operations on bowhead whales are as described above for the Beaufort Sea and would likely be similar for the Chukchi Sea. Drilling operations in the Chukchi Sea would likely initially occur in areas on federal leases for which exploration plans have recently been submitted or would be submitted during the time period of this EIS and where there have been recent requests for approval of ancillary activities. It is anticipated that either a drillship with eight to twelve support vessels or jackup rig with two to three support vessels would be used for exploratory drilling between early July and late October.

The drilling unit and support vessels typically do not enter the Chukchi Sea until after July 1 when most of the spring bowhead migration is complete. Few bowheads are expected to be encountered during the early season drilling operations, minimizing any effects at that time. Drilling operations occurring during September and October could potentially disturb and displace bowheads migrating through and across the Chukchi Sea.

Anticipated impacts of these activities, in terms of magnitude (medium), duration (interim), extent (local), and context (unique) would be similar to those described above for the Beaufort Sea. However, impacts are anticipated on a smaller number of animals based on the fact that these activities and bowhead whale migration in the Chukchi would only co-occur for a short period of time.

Associated Vessels and Aircraft

Known and potential effects of support vessel and aircraft on bowhead whales in the Chukchi Sea are as described above for the Beaufort Sea and would be expected to be similar for the Chukchi Sea.

Bowhead whales feeding and migrating in the Chukchi Sea could encounter numerous seismic vessels, support vessels, and associated aircraft. The number of kilometers transited by seismic and various types of support vessels in the Chukchi Sea in 2006 to 2008 ranged from 48,100 km (29,888 mi) (2007) to 106,838 km (66,386 mi) (2006) (Funk et al. 2010). Vessel sounds vary by vessel size and type, as well as vessel operating conditions. Vessel sounds measured the Chukchi Sea since 2007 yielded radii to 120 dB re 1 μPa between 360 m (1180 ft) for smaller vessels and 19 km (11.8 mi) for the largest vessels with powerful thrusters, with a mean value of 4.4 km (2.7 mi) (LGL Alaska Research Associates, Inc. et al. 2013). Offshore acoustic detections of bowhead whales during a period in mid-September 2012 coincided with the occurrence of numerous support vessels on standby to the southeast of the Burger drill site, suggesting that whales were not actively avoiding the area (LGL Alaska Research Associates, Inc. et al. 2013). The extent of disturbance depends on the areas in which vessels are transiting or operating, the number in a given area, and the time of operation. Bowheads feeding near shore in the northeast Chukchi Sea may be in the flight path for support flights and transits between Wainwright and Nome and possibly more susceptible to disturbance.

Based on the criteria defined in Table 4.5-18, anticipated impacts of these activities, in terms of magnitude (medium), duration (interim), extent (local), and context (unique) would be similar to those described above for the Beaufort Sea. However, impacts should affect a smaller number of animals based on the fact that these activities and bowhead whale migration in the Chukchi Sea would only co-occur for a short period of time.

Hearing Impairment, Injury, and Mortality

Although the likelihood of such impacts occurring is considered highly unlikely, the primary direct mechanisms of potential hearing impairment, injury, or mortality due to oil and gas exploration activities are hearing loss or damage (auditory injury) and collisions with vessels. The potential effects of a VLOS, which is considered improbable and for which incidental take would not be authorized by NMFS under any alternative, are discussed separately in Section 4.10.

Auditory Impairment (TTS and PTS)

Noise induced TS (including TTS and PTS) is described above. The potential for seismic airgun pulses to cause acoustic injury in marine mammals is not well understood (Gedamke et al. 2011), and data on levels or properties of sound that are required to induce TTS are lacking for baleen whales. Recent simulation models, using data extrapolated from TTS in toothed whales, suggest baleen whales 1 km (0.62 mi) or more from seismic surveys could potentially be susceptible to TTS (Gedamke et al. 2011). There is no information on TTS or PTS specifically for bowhead whales.

Because bowhead whales generally respond to loud noise by moving away, they are less likely to suffer hearing loss from increased noise. They are not likely to remain close enough to a large airgun array long enough to incur TTS, let alone PTS. The levels of successive pulses received by a marine mammal would increase and then decrease gradually as the seismic vessel approaches, passes and moves away, with periodic decreases also caused when the animal goes to the surface to breath, reducing the probability of the animal being exposed to sound levels large enough to elicit PTS. However, data suggest that exposures of longer duration and lower levels can lead to more TTS (i.e., onset at lower level and greater

amount of TTS) compared to exposures of higher level and short duration with the same cumulative sound exposure level (Finneran et al. 2010, Kastak et al. 2005, 2007, Kastelein et al. 2012a, b, Mooney et al. 2009), and seismic airguns can ensonify larger areas to higher levels in which whales may remain in the proximity of for longer times. This, in combination with the fact that monitoring reports include occasional observations of bowheads within the 180-dB zone of seismic surveys suggests that TTS and PTS, though unlikely, cannot be entirely ruled out.

Since bowhead whales appear to be more tolerant of noise when feeding, work is needed to determine potential effects of repeated exposure to loud noise at distances tolerated in feeding areas. The potential for increased noise to cause physiological stress responses should also be considered, as it is not currently known (NMFS 2011a). Obtaining data on stress responses in large free-swimming whales would require potentially disruptive invasive techniques.

Section 4.2.6.3 outlines NMFS final revisions to auditory injury thresholds. NMFS applied these thresholds to the types of sources analyzed in this EIS (seismic airguns and drilling sources of similar size) and found that the resulting distances at which injurious exposures could not be ruled out (i.e., those at which PTS might be incurred) were similar to those calculated using the 180 and 190-dB historical thresholds (though actually notably smaller for mid-frequency cetaceans and otairids), meaning that the revisions to the auditory injury thresholds do not notably change any of the conclusions articulated in earlier versions of the EIS. As noted previously, most individual marine mammals are expected to avoid loud sounds at distances that would lead to PTS, and standard mitigation measures to shut down airguns if individuals approach within distances associated with injurious effects are expected to help minimize effects. That said, the potential for PTS cannot be ruled out for bowheads or other low-frequency cetaceans and phocids and is considered highly unlikely to occur for mid-frequency cetaceans and otariids.

Determining effects intensity is not possible, without instances of noise exposures severe enough to result in observed mortality where cause of death could be attributed to sound impulses. There are no known such incidences with bowhead whales. The duration of impact would be temporary for TTS but permanent if PTS were to occur. The extent of such impacts would be local and the context is important, since bowhead whales are listed as endangered (and the population is increasing).

Ship Strikes

Marine vessels could potentially strike bowhead whales, causing either injury or death. Incidence of ship strikes appears low, but could rise with increasing vessel traffic. Only three ship-strike injuries were documented in the 236 bowhead whales examined from the subsistence harvest from 1976 to 1992 (George et al. 1994). All of the injuries indicate the whales were struck by propellers of large (>30 m [>98.4 ft]) ships.

The low incidence of observed ship strikes, as of the early-1990s, was likely an artifact of the comparatively low rate of vessels passing through most of the bowhead's range or that many bowheads struck by ships do not survive (George et al. 1994). Ship strikes are a major cause of mortality and serious injury in North Atlantic right whales, accounting for 35 percent of deaths from 1970 to 1999 (Knowlton and Kraus 2001). Experimental playback studies revealed that right whales did not respond to sounds of approaching vessels or to actual vessels, suggesting habituation to engine sounds that are ubiquitous throughout most of their range (Nowacek et al. 2004). Most bowhead whales, in contrast, show strong avoidance reactions to approaching ships. Eskimo hunters report that bowheads are less sensitive to approaching boats when they are feeding (George et al. 1994), leaving them more vulnerable to vessel collisions.

The frequency and severity of ship strikes is influenced by vessel speed. The potential for collision increases at speeds of 15 kn and greater (Laist et al. 2001, Vanderlaan and Taggart 2007). For the activities considered under Alternative 2, speeds for most source vessels are relatively slow

(approximately 3 to 5 kn) during oil and gas exploration activities. Transit speeds, however, are likely to be much higher. Seismic survey source vessel transit speeds are, for example, estimated at 8 to 12 kn (refer to Chapter 2, Alternatives for details), suggesting that, if collisions were to occur, they are more likely when vessels are in transit than when conducting active exploration operations. Vessels transiting to the Beaufort or Chukchi seas from Dutch Harbor at the start of the open water season, or returning across these areas to the Bering Strait at the end of the season, transiting between sites, or for resupply in and out of Nome or Wainwright in the Chukchi Sea or Prudhoe Bay in the Beaufort have the highest chance of encountering migrating bowheads or aggregations feeding in more coastal regions of the northeast Chukchi and between Point Barrow and Smith Bay in the Beaufort Sea.

The reported incidence of ship strikes is low, but, since collisions have occurred in the past, the intensity of the impact should be considered medium. The impact would be temporary, although the results (injury or mortality) would be permanent for the individual whale. The extent of impact would be local, given the infrequency of occurrence and the non-random distribution of both bowhead whales and exploration activity in the EIS project area. The context would be important, since bowhead whales are listed as endangered and the population is increasing Refer to Table 4.5-18 for marine mammal impact criteria definitions.

Small Fuel Spill

There is the potential for bowhead whales to be exposed to small fuel spills of less than 50 bbl (see Section 4.2.7). If a small spill were to escape containment or response measures, it would not persist very long, resulting in few opportunities to contact bowhead whales. Further, vessel activity associated with spill response would likely keep bowhead whales out of the spill area, and individual whales would likely avoid the spill by leaving the area during spill response activities. Oil generally poorly adheres to the skin of mysticete whales, and cetaceans are believed to have the ability to detect and avoid oil spills (Geraci, 1990; St. Aubin, 1990). Moreover, the weathering process should act to quickly break up or dissipate oil/fuel through the local environment to harmless residual levels that would eventually become undetectable. Therefore, small spills are anticipated to have no more than a negligible level of effect on bowhead whales.

Habitat Alterations

Alterations to marine mammal habitat could occur through physical changes, such as to the substrate or sea ice, pollution in the water column, alterations to prey species, or impacts on acoustic habitat relied upon by marine mammals for communication and other functions. This subsection describes the potential impacts of the various activity types on bowhead whale habitat (in the broader sense mentioned here).

Oil and gas exploration activities that may result in alteration of habitat include disturbance of sea ice from icebreaking, disturbance of benthic sediments during drilling, and contamination of the marine environment from discharge of drilling muds and other waste streams from ships and support facilities. Effects of icebreaking and exploratory drilling are discussed above in the introduction to effects on marine mammals (Section 4.5.2.4). Potential effects of a very large oil spill, including long-term displacement from areas impacted by oil, are discussed in Section 4.10. Additional details and impact assessments are provided here.

Potential impacts of drilling mud discharged into the marine environment are among concerns expressed by Iñupiat subsistence hunters:

> *I've experienced drilling mud on an iceberg north of Northstar at that time when Northstar was in a stage of being developed. So there were quite a few drilling muds being caught at -- on Northstar on a real calm, calm day. Not even one marine mammal was inside it. And you could hear that Northstar drill rig pounding away. Not one marine mammal, not even one waterfowl was sighted. And the only thing we encountered was an iceberg totally covered with drilling mud.*

> *It's not a natural mud.* (Testimony provided by Archie Ahkiviana at the Nuiqsut Public Scoping Meeting for this EIS, March 11, 2010).

Adverse effects of discharges on bowhead whales are directly related to whether or not any potentially harmful substances are released into the marine environment and whether they rapidly dilute or bioaccumulate through the food chain. Bowhead whales are long lived, and some individuals potentially could accumulate contaminants. Bowhead whales, however, feed on lower trophic level organisms (zooplankton) so are considered at lower risk of bioaccumulation of contaminants, such as persistent organic compounds, than higher level consumers. Levels of persistent organic compound concentrations in samples collected from bowhead whales in Alaska are low compared to other marine mammals (O'Hara and Becker 2003).

Drill cuttings and drilling mud discharges are regulated by either the EPA NPDES permits or the ADEC APDES permits as detailed in State waters in the Beaufort Sea.Section 4.5.1.5. The impact of drill cuttings and drilling mud discharges would be medium in intensity, local in extent,extent and temporary in duration. Drill cuttings and mud discharges could temporarily displace marine mammals a short distance from the drilling site. The EPA modeled a hypothetical 750 bbl/hr discharge of drilling fluids in 20 m (66 ft) of water in the Beaufort and Chukchi seas and predicted a minimum dilution of 1,326:1 at 100 m (330 ft) from the discharge point (Shell 2011a). Discharged drilling fluid should be well diluted within 100 m (330 ft) so that any impacts would be highly localized and temporary, assuming whales continue to swim through or past the discharge plume. If toxic contaminants are present in discharges, only a small area of potential habitat and prey base might be contaminated. Consequently, the resulting population-level effects would be negligible.

Bottom-founded drilling units or gravel islands could impact small areas of benthic habitat that support epibenthic prey aggregations that bowhead whales feed on, increasing turbidity or sediment suspension in the water column (Mocklin 2011). Exploration drilling on past and current leases would add incrementally to potential discharges into the Beaufort and Chukchi seas but would remain restricted to areas immediately surrounding exploration drilling activity.

Additionally, the acoustic habitat, within which whales use sound to communicate and detect prey, predators, and other environmental cues, can be temporarily altered by the presence of sounds in the frequency bands of the signals of interest for the whales. Depending on the decibel level, frequency, and duration of these sounds, these acoustic habitat alterations may result in reduced ability to detect or interpret some important sounds.

Section 4.5.2.4.9 and Appendix F outline the results and limitations of a first-order aggregate and chronic assessment of oil and gas activities in the Arctic conducted by NMFS in response to public comments on the DEIS and SEIS. Broadly, results suggest that even with the lower predicted activity levels in Alternative 2, substantial losses of listening area (up to 98%) and bowhead communication space (up to 20%), to a lesser degree, would occur in the Beaufort Sea area from July to mid-October (far less loss was noted in the Chukchi). As noted in section 4.5.2.4.9, there is evidence indicating significant reductions in listening area or communication space can negatively affect aquatic animals. Though data are lacking to document links to population consequences for long-lived and often wide-ranging species such as marine mammals, chronic noise effects that impair an animal's ability to detect critical acoustic cues over a relatively large area for 3.5 months must be carefully considered, especially for bowhead whales, which migrate through with calves under conditions where communication is important to maintain group cohesion.

Effects on Zooplankton

In a review of available information on the effects of seismic sound on invertebrates, the Canadian Department of Fisheries and Oceans (DFO) reported lethal and/or sublethal effects have sometimes been observed in invertebrates (e.g., crustaceans, gastropods) exposed to airgun sounds at distances of <5 m

(<16.4 ft) under experimental conditions (DFO 2004). They considered exposure to seismic sound unlikely to result in direct invertebrate mortality, although invertebrates may exhibit short-term behavioral reactions to sound (DFO 2004). They found few studies on the effects of seismic noise on zooplankton. Zooplankton very close to the seismic source may react to the shock wave, but effects are expected to be local (LGL 2010). Potential non-seismic effects on zooplankton are noted above and in the respective sections on Lower Trophic Levels (see, for example, 4.5.2.1).

Potential impacts to bowhead whale habitat (including from discharge and to zooplankton and acoustic habitat) from oil and gas exploration activities permitted under Alternative 2 would, based on the criteria defined in Table 4.5-18, be of low to medium intensity. Most impacts would be local in the area immediately adjacent to the impacts (discharges, sediment disruption, or icebreaking), but disruptions to acoustic habitat could occur across a larger area. Most impacts would also be temporary, though longer-term and regional effects could occur to acoustic habitat and through the process of bioaccumulation through the food web..

4.5.2.4.10.2 Conclusion

Like in other resource sections, consideration of the effects of implementation of the required standard mitigation measures is included in the conclusion immediately below. Unlike in other resource sections, the Standard Mitigation Measure section is *not* included immediately prior to this Conclusion section, but rather, the separate section analyzing the measures themselves is included once at the end of the Marine Mammal section after all of the individual species sections because the measures apply to multiple species and including them multiple times in separate species sections would be repetitive and potentially confusing.

Oil and gas exploration activities in the Beaufort and Chukchi seas, as analyzed under Alternative 2, would likely cause behavioral disturbance to bowhead whales, including varying degrees of disturbance to feeding, resting, or migrating bowhead whales depending on actual level of effort, type of activity, time of year, and whether activities run concurrent in the Beaufort and Chukchi seas. Disturbance could lead to displacement from and avoidance of areas of exploration activity. The EIS project area encompasses a portion of bowhead whale habitat between the Bering Strait and Canadian border, so leaving the area entirely to avoid impacts is not likely. The duration of disturbance (and acoustic habitat disturbance) from oil and gas activities is expected to be of long-term duration, lasting less than six months, but repeating over multiple years. Surveys utilizing icebreakers could cause avoidance and displacement over a larger radius with the additional noise input from the icebreaking activities, but the period of time over which this activity would overlap with bowhead whale presence is much shorter. Although bowhead whales react to approaching vessels at greater distances than they react to most other activities, most observed disturbance reactions to vessels and aircraft appear to be brief. The extent of the impact will depend on the number of exploration activities and associated support vessels in an area, but, for individual sound sources, impacts are expected to be local. However, over the course of the season and considering the maximum level of activity potentially conducted under this activity, and considering areas that are potentially ensonified above 120 dB, the geographic scale could be considered regional.

Because whales respond behaviorally to loud noise, and because of the required standard mitigation measures, they are less likely to suffer auditory damage from increased noise due to oil and gas exploration activities. Additionally, based on the required standard mitigation measures, impacts from vessel strikes are considered unlikely.

The geographic area and extent of the population over which effects would be felt (especially considering the distances over which bowhead whales communicate and seismic sounds travel) would likely increase with multiple activities occurring simultaneously or consecutively throughout much of the summer-fall range of this population. Potential long-term effects from repeated disturbance, displacement or habitat disruption on an extremely long-lived species such as the bowhead whale are unknown. The Western Arctic stock of bowhead whales has, however, continued to increase at an estimated 3.7 percent per year

despite past and present exploration activities within their range (Givens et al. 2013). It is not currently possible to predict which behavioral responses to anthropogenic noise might result in population-level effects for marine mammals, such as bowheads, in the future (NRC 2005).

Bowhead whales are listed as endangered and impacts are expected to occur within an important migratory corridor where almost all mothers and calves will pass through within a year, which places them in the context of being a unique resource in the region. Potential impacts of the combined activities associated with oil and gas exploration considered under Alternative 2 on bowhead whales would likely be of medium to high intensity, interim to long-term duration, and on a local to regional geographic scale. Evaluated collectively, and with consideration given to reduced adverse impacts through the implementation of the standard mitigation measures, as appropriate, the overall impact to bowhead whales is likely to be moderate.

Table 4.5-20 Effects Summary for Bowhead Whales

Type of effect	Impact Component	Effects Summary	
Behavioral disturbance	Magnitude or Intensity	Low	
		Medium	Lower to moderate levels of activity within this Alternative (akin to recent years) would not result in disturbance of> 30% of population disturbed
		High	Impacts from max level activity expected to exceed take of 30% of population
	Duration	Temporary	At the lower levels of this Alternative, effects are closer to temporary - could be only couple smaller activities with short-term effects on individuals – and possible could be years with none
		Interim	In most Alternative configurations, all activity types last multiple months and some level of activities are recurring over multiple successive years. Effects to individuals could occur acros multiple months, though less likely for bowheads that migrate through.
		Long-term	
	Geographic Extent	Local	When the total area ensonified above the behavioral harassment thresholds (160 dB for seismic and 120 dB for drilling) is considered (Table 4.5-14b), the impacts are local.
		Regional	
		State-wide	
	Context	Common	
		Important	
		Unique	ESA-listed species, impacts across migratory corridor through which mother/calf pairs traverse, potential disruption of feeding and resting
Injury and mortality	Magnitude or Intensity	Low	Injury or death unlikely
		Medium	Though unlikely, cannot rule out PTS to small number of individuals
		High	
	Duration	Temporary	
		Interim	
		Long-term	Though unlikely, PTS would be permanent if incurred
	Geographic Extent	Local	Since unlikely, any few impacts would be considered local
		Regional	
		State-wide	
	Context	Common	
		Important	ESA-listed species, but population is increasing
		Unique	
Habitat alterations	Magnitude or Intensity	Low	Impacts to most habitat features are low in intensity
		Medium	Impacts to acoustic habitat are of medium intensity (~28% of EIS area ensonified over 120 dB, up to 98% lost listening area in some areas of Beaufort, and up to 20% lost bowhead communication space in some areas of Beaufort)
		High	
	Duration	Temporary	
		Interim	At the lower levels of this Alternative impacts are closer to interim, as could be only couple smaller activities – and possible could be years with none
		Long-term	In most Alternative configurations, all activity types last multiple months and some level of activities are recurring over multiple successive years.
	Geographic Extent	Local	It is possible that very low-level versions of this Alternative may result in only local effect.
		Regional	When the total area ensonified by all sources above 120 dB is considered (used to indicate where animals will hear it and the potential for masking exists), most scenarios will likely result in regional effects.
		State-wide	
	Context	Common	
		Important	
		Unique	ESA-listed species, impacts across migratory corridor through which mother/calf pairs traverse, potential disruption of feeding and resting

4.5.2.4.11 Beluga Whales

This section describes the potential effects of Alternative 2 to beluga whales. This information is in addition to the information provided in Sections 4.5.2.4.1 through 4.5.2.4.9, which is applicable to marine mammals more generally. Here, we include information specific to beluga whales.

4.5.2.4.11.1 Direct and Indirect Effects

The primary direct and indirect effects on beluga whales from activities associated with oil and gas exploration in the Beaufort and Chukchi seas considered under Alternative 2 would result from noise exposure. Ship strikes and habitat degradation are also possible. Sources of noise include 2D/3D seismic survey equipment (airgun arrays), echosounder and sonar devices associated with site clearance and shallow hazards surveys, support, monitoring and receiving vessels associated with these surveys, icebreaking activities, on ice vibroseis seismic surveys (Beaufort Sea only), exploratory drilling, and helicopter and fixed wing aircraft associated with the different programs. Details of these activities and associated components can be found in Chapter 2.

Behavioral Disturbance

2D/3D Seismic Surveys (July through November)

Anthropogenic noise from oil and gas exploration activities may elicit behavioral responses from beluga whales. The possible reactions by marine mammals are listed above; known reactions by beluga whales are included here and described and assessed by region and activity. Most of these mechanisms are common to both seas, and these potential effects are discussed together. Where activities or mechanisms are unique to one sea or the other, they are discussed separately. Beluga whales are observed in both seas. Vessels associated with the exploration activities identified in Chapter 2 introduce sound into the water and have a physical presence that could affect beluga whales. Although many of these vessels carried PSOs in the past, beluga whales are rarely seen from these vessels, particularly in the Chukchi Sea.

Miller et al. (2005) reported, based on observations collected during two years of seismic studies in the Beaufort Sea, that beluga whale sightings were unexpectedly high 20-30 km (12.4-18.6 mi) from the seismic vessel, and substantially lower 10-20 km (6.2-12.4 mi) from the vessel, indicating that whales may be avoiding operations by 10-20 km (6.2-12.4 mi). Studies of captive beluga whales have shown that they exhibit changes in behavior when exposed to strong, pulsed sounds similar in duration to those used in seismic surveys (Finneran et al. 2002a), but the received sound levels were relatively high before aversive behaviors were observed (peak to peak level >200 dB re 1 μPa). Behaviors such as vocalizing after the exposure and reluctance to station at the test site were observed (Finneran et al. 2002a). Similar behaviors were observed by a beluga whale exposed to a single underwater pulse similar to those produced by distant underwater explosions (Finneran et al. 2000). The applicability of these observations in trained, captive beluga whales exposed to a single transient sound to the natural environment of free-ranging animals exposed to multiple pulses over time, is unknown.

Most of the energy from airgun arrays is below 100 Hz, which is below the frequencies of calling and best hearing of beluga whales, however, behavioral observations indicate that they are not insensitive to sounds produced by these activities.

Anticipated impacts of 2D/3D surveys would be expected to be of medium magnitude (behavioral disturbance, but less than 30% of population affected), interim duration (between 1 and 6 months, and potentially not always occurring every year), local extent (not spanning more than 10% of the EIS area), and common to important context as, although beluga whales are not ESA-listed, industry activities will overlap with some areas of importance for belugas.

In-ice Seismic Survey (2D/3D) with Icebreaker Support (October to mid-December)

While not many studies have been conducted to evaluate the potential interference of icebreaking noise with marine mammal vocalizations, a few studies have looked specifically at icebreaking noise and beluga whales. Erbe and Farmer (1998) reported that the Canadian Coast Guard ship, *Henry Larsen*, ramming ice in the Beaufort Sea, masked recordings of beluga vocalizations at a signal-to-noise ratio of 18 dB. At least six of 17 groups of beluga whales appeared to alter their migration path in response to underwater playbacks of icebreaker sound (Richardson et al., 1995). Received levels from the icebreaker playback were estimated at 78-84 dB in the 1/3-octave band centered at 5,000 Hz, or 8-14 dB above ambient. If beluga whales reacted to an actual icebreaker at received levels of 80 dB, reactions would be expected to occur at distances on the order of 6.2 mi (10 km). Finley et al. (1990) also reported beluga avoidance of icebreaker activities in the Canadian High Arctic at distances of 22-31 mi (35-50 km). In addition to avoidance, changes in dive behavior and pod integrity were also noted. However, an in-ice seismic survey cannot be conducted in ice thick enough to require ramming to break it up.

Erbe and Farmer (2000) modeled zones of impact for the bubbler system noise in addition to the propeller cavitation (ramming) noise. The propagation model predicted that icebreaker bubbler system noise could mask beluga whale communication out to 14 km (8.7 mi) from the vessel over the continental slope, as measured near the surface. The modeled zone of behavioral disturbance for the bubbler system noise extended to approximately 32 km (19.9 mi). Based on historical modeled estimates, in-ice surveys likely result in a larger number of harassed belugas than other activity types.

While Finley and Green (1993) observed belugas reacting to icebreaking from 50 km away, the same rule cannot be perfectly applied to ice management, which is the ice-related activity typically anticipated during the open water season. Unlike ice-breaking, which relies on an icebreaker ship smashing through areas of sea ice, ice management involves pushing or diverting ice away from operations at a relatively slow speed. Consequently ice management activities are expected to be much “quieter” than ice breaking activities, resulting in a much smaller area of effects on beluga whales. Though similar in that they both involve the use of ships with icebreaking capabilities, the two activities are very different, as are the disturbances created by these different activities.

Anticipated impacts of in-ice seismic surveys (2D/3D) with icebreaker support, in terms of magnitude (medium), duration (interim), extent (local), and context (important) would be generally similar to those described for 2D/3D seismic surveys above.

Ocean-Bottom-Cable or Node Survey (July to October)

An OBC/OBN seismic survey typically covers a smaller area than the streamer surveys discussed above and may spend several days in an area. One such survey is anticipated in the Beaufort Sea under Alternative 2. Beluga whales are present throughout the Beaufort Sea during this time period and may be concentrated in nearshore areas. Reactions to sounds from OBC/OBN surveys are similar to those reported for 2D/3D steamer seismic surveys. Anticipated impacts of OBC/OBN surveys, in terms of magnitude (medium), duration (interim), extent (local), and context (important) would be similar to those described for 2D/3D seismic surveys above. Although disturbance effects may extend 20 to 30 km (12.4 to 18.6 mi) from the sound source, with one OBC/OBN survey anticipated in the Beaufort Sea, short-term effects should remain local.

Site Clearance and High Resolution Shallow Hazards Survey Programs (July to November)

High-resolution shallow hazards surveys are of short duration, and the airguns generate lower energy sounds and have a smaller zone of influence than the larger airgun arrays used for 2D/3D seismic surveys (NMFS 2010b). The radii of ensonification at 120, 160, 180, and 190 dB re 1 μPa rms were calculated for sound sources proposed for use in 2010. Radii calculated for the 40 in^3 airgun were 14,000 m (45,932 ft), 1,220 m (4,003 ft), 125 m (410 ft), and 35 m (115 ft) for the respective sound source levels. The beam

widths of these sources are quite narrow, which would only expose marine mammals to the sounds for one or two pulses at most if the animal swims in the direct beam width of the source. Ensonified zones were not calculated for side scan sonar, single-beam or multi-beam echosounders, or for the bathymetric sonar (NMFS 2010b). The higher frequency sub-bottom profilers, side scan sonar, and echosounders often produce sounds at high enough energy to result in disturbance, to beluga whales. Captive bottlenose dolphins and a beluga whale exhibited changes in behavior when exposed to 1 s tonal signals at frequencies similar to those emitted by some of these higher frequency sound sources and to shorter broadband pulsed signals. Behavioral changes typically involved what appeared to be deliberate attempts to avoid the sound exposure (Schlundt et al. 2000, Finneran et al. 2002a, Finneran and Schlundt 2004). Based on some recent reports (Southall et al. 2013), NMFS recognizes that these types of sound sources can sometimes result in behavioral responses that rise to the level of take. NMFS will take this into consideration when analyzing MMPA requests that include the use of such equipment.

Based on results of noise studies on captive and wild populations of beluga whales, belugas would likely avoid the area directly around the shallow hazard operations using the higher frequency equipment, resulting in a temporary, local effect. If such types of shallow hazard operations were conducted in areas where belugas are feeding or nursing, continued operations may result in displacement from these important habitats. Anticipated impacts of these surveys are similar to those of 2D/3D surveys, but lower in magnitude and extent, and are generally characterized as: magnitude (low), duration (interim), extent (local), and context (common to important) would be similar to those described for 2D/3D seismic surveys above.

On-ice Vibroseis Survey (January to May)

Beluga whales are not likely to experience impacts resultant from an on-ice survey due to their absence from the Beaufort Sea during the winter months. If, however, the activity continues into April and May, it could coincide with the spring migration of the Beaufort Sea stock.

Exploratory Drilling (July through October)

Reactions of beluga whales to drillship operation sounds vary. As summarized in Richardson et al. (1995), belugas are often observed near drillsites within 100 to 150 m (328.1 to 492.1 ft) from artificial islands, which are production islands and are different than exploratory drilling platforms. However, belugas swimming in the spring leads change course when they came within 1 km (0.62 mi) of a drillship and exhibited aversive behavior when support vessels were operating near the drillship (Richardson et al. 1995). Reactions of belugas (captive and wild) to playbacks of the semisubmersible drillship *SEDCO 708* indicate that belugas exhibit slight avoidance reactions to drillship sounds (Richardson et al. 1995). Furthermore, belugas may not be able to detect the lower frequency sounds of drillships, which usually emit sounds below 1 kHz because they are below their best hearing sensitivity.

Exploration activities (including anchor handling and drilling) in the Beaufort Sea in 2012 occurred on the continental shelf. Belugas sighted from aerial surveys during these activities were off the shelf break, outside of the soundscape created for acoustic analysis (LGL Alaska Research Associates, Inc. et al. 2013). If calculated out to the location of the beluga sighting, the exposure level would have been between 100 and 103.7 median SPL [dB re 1 μPa (rms)], the same median SPL for beluga sightings in the absence of industrial activity in the area. Industrial sound levels to which beluga whales along the shelf break are exposed during drilling activity in the Beaufort Sea are, therefore, similar to typical ambient sound levels in the Beaufort Sea (LGL Alaska Research Associates, Inc. et al. 2013).

Anticipated impacts of exploration activities to beluga whales are likely to be medium in terms of magnitude, interim in duration, local in extent, and important in context.

Associated Vessels and Aircraft

Helicopter noise may be a source of disturbance to beluga whales, particularly during exploratory drilling crew transfers. During spring migration in the Beaufort Sea, beluga whales reacted to helicopter noise more frequently and at greater distances than did bowhead whales (Patenaude et al. 2002). Most reactions occurred when the helicopter passed within 250 m (820 ft) lateral distance at altitudes <150 m (492 ft). Neither species exhibited noticeable reactions to single passes at altitudes >150 m (492 ft). Belugas within 250 m (820 ft) of stationary helicopters on the ice with the engine running showed the most overt reactions. Whales were observed to make only minor changes in direction in response to sounds produced by helicopters, so all reactions to helicopters were considered brief and minor. Patenaude et al. (2002) noted that fewer belugas reacted to a Twin Otter than to a helicopter (3.2% instead of 38%).

Lesage et al. (1999) report that beluga whales changed their call type and call frequency when exposed to vessel noise. Beluga whales have been documented swimming rapidly away from ships and icebreakers in the Beaufort Sea when a ship approached to within 35 to 50 km (21.7 to 31.1 mi) and received levels ranged from 94 to 105 dB re 1 µPa in the 20 to 1,000 Hz band, and they may travel up to 80 km (49.7 mi) from the vessel's track (Finley et al. 1990). In addition to avoidance, changes in dive behavior and pod integrity were also noted.

Anticipated impacts of vessels and helicopters, are considered low in magnitude, interim in duration, and important in context. The extent of the impact would depend on the number of support vessels in an area, but, for individual activities, impacts are expected to be local. Multiple activities in one area or in several areas across the migratory corridor could result in a broader, regional impact.

Hearing Impairment, Injury, and Mortality

The primary mechanisms of potential hearing impairment, injury, or mortality of beluga whales due to oil and gas exploration activities are hearing loss or damage (auditory injury) and collisions with vessels.

Auditory Impairment

Noise-induced threshold shift, including TTS and PTS, is described in Section 4.5.2.4.

NMFS currently considers the appropriate metric for TTS levels to be the rms received level, which is typically 10 to 15 dB higher than the SEL for the same pulse, therefore, a single airgun pulse would need to have a received level of ~196 to 201 dB to result in a brief, mild TTS in beluga whales. As also noted, NMFS is considering revisions to these injury thresholds, although even with the changes, the 180-dB rms mitigation zone is still expected to protect mid-frequency hearing specialists from potential injury.

As reported in the Section 4.5.1.4 (Acoustics), distances to the 180 dB rms received level from various sizes of airgun arrays are <2,570 m (8,432 ft). Therefore, TTS would be expected if beluga whales remained within this distance from the source vessel during airgun operations. However, beluga whales have been observed to avoid seismic vessels. Some beluga whales summering in the Eastern Beaufort Sea may have avoided the area around seismic program using 2 arrays with 24 airguns per array by 10 to 20 km (6.2 to 12.4 miles), although some occurred as close as 1,540 m (5,052 ft) to the operations (Miller et al. 2005). Based on these observed reactions, the likelihood of beluga whales being exposed to adverse sound levels is low. Recent seismic monitoring studies have confirmed that belugas remained further away from seismic operations than has been shown for other odontocetes (Harris et al. 2007).

Researchers have derived TTS information for odontocetes from studies on the bottlenose dolphin and beluga. For the harbor porpoise tested, the received level of airgun sound that elicited onset of TTS was lower (Lucke et al. 2009). If these results from a single animal are representative, it is inappropriate to assume that onset of TTS occurs at similar received levels in all odontocetes (cf. Southall et al. 2007). Some cetaceans apparently can incur TTS at considerably lower sound exposures than are necessary to elicit TTS in the beluga or bottlenose dolphin Utilizing the evoked-potential technique in captive animals, Popov et al. (2013) tested two belugas for temporary threshold shift (TTS) after exposure to loud noise.

This fatiguing noise had a 0.5 octave bandwidth, with center frequencies ranging from 11.2 to 90 kHz, a level of 165 dB re.1µPa and exposure durations from 1 to 30 min. The highest TTS with the longest recovery duration was produced by noises of lower frequencies (11.2 and 22.5 kHz) and appeared at a test frequency of +0.5 octave. At higher noise frequencies (45 and 90 kHz), the TTS decreased. The TTS effect gradually increased with prolonged exposures ranging from 1 to 30 min. These authors found considerable TTS differences between the two whales tested.

Section 4.2.6.3 outlines NMFS final revisions to auditory injury thresholds. NMFS applied these thresholds to the types of sources analyzed in this EIS (seismic airguns and drilling sources of similar size) and found that the resulting distances at which injurious exposures could not be ruled out (i.e., those at which PTS might be incurred) were similar to those calculated using the 180 and 190-dB historical thresholds for low-frequency specialists and phocids, but were actually notably smaller for mid-frequency cetaceans and otariids. As noted previously, most individual marine mammals are expected to avoid loud sounds at distances that would prevent PTS, and standard mitigation measures to shut down airguns if individuals approach within distances associated with injurious effects are expected to help minimize effects. That said, the potential for PTS cannot be ruled out but is considered *highly* unlikely to occur for mid-frequency cetaceans and otariids.

Exploratory drilling activities are not anticipated to induce TTS or PTS, as source levels for the drill ship and other equipment are typically between 175 and 185 dB re 1 µPa rms.

Ship Strikes

Marine vessels could potentially strike beluga whales, causing either injury or death. Incidence of ship strikes are currently low but could rise with increasing vessel traffic.

The frequency and severity of ship strikes is influenced by vessel speed. The potential for collision increases at speeds of 15 kn and greater (Laist et al. 2001, Vanderlaan and Taggart 2007). Most source vessel speeds are relatively slow (approximately 3 to 5 kn) during oil and gas exploration activities. Transit speeds, however, are likely to be much higher. Seismic survey source vessel transit speeds are, for example, estimated at 8 to 20 kn (refer to Chapter 2, Alternatives for details), suggesting that, if collisions were to occur, they are more likely when vessels are in transit. Vessels transiting to the Beaufort or Chukchi seas from Dutch Harbor at the start of the open water season, or returning across these areas to the Bering Strait at the end of the season, transiting between sites, or for resupply in and out of Nome or Wainwright in the Chukchi Sea or Prudhoe Bay in the Beaufort have the highest chance of encountering migrating and feeding beluga whales. Based on the required standard mitigation measures, impacts from vessel strikes are considered unlikely.

Small Fuel Spill

There is the potential for beluga whales to be exposed to small fuel spills of less than 50 bbl (see Section 4.2.7). However, few beluga whales are anticipated to occur in the vicinity of oil and gas activities and few would be exposed to a spill. Moreover, if a small spill were to escape containment or response measures, it would dissipate over a few days, resulting in few opportunities to contact beluga whales. Also, vessel activity associated with spill response would likely keep beluga whales out of the spill area, and individual whales would likely avoid the spill by leaving the area during spill response activities. Small spills are anticipated to have no more than a negligible level of effect on beluga whales.

Habitat Alteration

Alterations to marine mammal habitat could occur through physical changes, such as to the substrate or sea ice, pollution in the water column, alterations to prey species, or impacts on acoustic habitat relied upon by marine mammals for communication and other functions. This subsection describes the potential impacts of the various activity types on bowhead whale habitat (in the broader sense mentioned here).

Oil and gas exploration activities that may result in the alteration of beluga whale habitat include drill cuttings and drilling mud discharges from exploratory drilling. The impact of drill cuttings and drilling mud discharges would be local and temporary. Drill cuttings and mud discharges could temporarily displace marine mammals a short distance from the drilling location. Based on a hypothetical EPA model in the Beaufort and Chukchi seas, the potential source of an impact, the discharged drilling fluid is diluted to the extent that any impacts would be minimal and temporary, due to the whale's motility, assuming that the animal continues to swim through the discharge plume (Shell 2011a).

Discharges related to drilling would occur and, if released into the marine environment, effects would remain local in extent in relation to affecting whale habitat and prey populations. The effects of such discharges are anticipated to remain local as a result of rapid deposition and dilution and potential contamination (if toxic contaminants are present in discharges) of an extremely small proportion of the habitat or the prey base available to beluga whales; thus, population-level effects would be negligible, although interim in duration.

Additionally, the acoustic habitat, within which whales use sound to communicate and detect prey, predators, and other environmental cues, can be temporarily altered by the presence of sounds in the frequency bands of the signals of interest for the whales. Depending on the level, frequency, and duration of these sounds, these acoustic habitat alterations can result in reduced ability to detect or interpret important sounds.

Section 4.5.2.4.9 and Appendix F outline the results and limitations of a first-order aggregate and chronic assessment of oil and gas activities in the Arctic conducted by NMFS in response to public comments on the DEIS and SEIS. Broadly, results suggest that even with the lower predicted activity levels in Alternative 2, substantial losses of listening area (up to 98%) will occur in the Beaufort Sea area from July-mid-October. As noted in section 4.5.2.4.9, there is ample evidence to support the fact that significant reductions in listening area can negatively affect aquatic animals. And, while data are lacking to document links to population consequences for long-lived and often wide-ranging species such as marine mammals, it is clear that chronic noise effects that impair an animal's ability to detect critical acoustic cues over a relatively large area for 3.5 months must be carefully considered.

Acoustic impacts to beluga whale habitat are determined to be medium in magnitude, interim in duration, local in extent, and important in context.

4.5.2.4.11.2 Conclusion

Like in other resource sections, consideration of the effects of implementation of the required standard mitigation measures is included in the conclusion immediately below. Unlike in other resource sections, the Standard Mitigation Measure section is *not* included immediately prior to this Conclusion section, but rather, the separate section analyzing the measures themselves is included once at the end of the Marine Mammal section after all of the individual species sections because the measures apply to multiple species and including them multiple times in separate species sections would be repetitive and potentially confusing.

Oil and gas exploration activities in the Beaufort and Chukchi seas, as analyzed under Alternative 2, would likely cause behavioral disturbance to beluga whales, including varying degrees of disturbance to feeding, calving, or migrating whales depending on actual level and location of effort, type of activity, time of year, and whether activities run concurrent in the Beaufort and Chukchi seas. Disturbance could lead to displacement from and avoidance of areas of exploration activity. The EIS project area encompasses a large portion of beluga whale habitat between the Bering Strait and Canadian border, so leaving the area entirely to avoid impacts is not likely. The duration of disturbance, and acoustic habitat disturbance, from oil and gas activities is expected to be of interim to long-term duration, lasting less than six months, but repeating over multiple successive years. Surveys utilizing icebreakers could cause avoidance and displacement over a larger radius with the additional noise input from the icebreaking

activities. The extent of the impact will depend on the number of exploration activities and associated support vessels in an area, but all though impacts are expected to be local in the context of behavioral disturbance, they will likely be regional in the context of habitat alteration when acoustic habitat is considered.

Because whales respond behaviorally to loud noise, and because of the required standard mitigation measures, they are less likely to suffer auditory damage from increased noise due to oil and gas exploration activities. Of note also, although they still respond to these sources, the low frequency sounds from most exploration activities are outside of the range of highest hearing sensitivity for belugas and less likely to overlap with important interspecies communication. The magnitude of impacts is moderate. Additionally, based on the required standard mitigation measures, impacts from vessel strikes are considered unlikely.

Beluga whales in the Arctic are not listed under the ESA. They have feeding and calving areas that are important to the populations, making their context important for behavioral disturbance and habitat alterations.

The intensity and duration of the various effects and activities considered are mostly medium and interim. However, potential long-term effects from repeated disturbance are unknown. Currently, population trends for the Beaufort stock cannot be estimated and are not thought to be declining in the Chukchi stock. Although, individually, the various activities may elicit local effects on beluga whales, the area and extent of the population over which effects occur will likely increase with multiple activities occurring simultaneously or consecutively throughout much of the spring-fall range of the Arctic populations. The summary impact level of Alternative 2 on beluga whales would be considered moderate.

Table 4.5-21 Effects Summary for Beluga Whales

Type of effect	Impact Component	Effects Summary	
Behavioral disturbance	Magnitude or Intensity	**Low**	
		Medium	Behavioral harassment occurring, but likely < 30% of population disturbed
		High	
	Duration	**Temporary**	At the lower levels of this Alternative effects are closer to temporary - could be only couple smaller activities with short-term effects on individuals – and possible could be years with none
		Interim	In most Alternative configurations, all activity types last multiple months and some level of activities are recurring over multiple successive years. Effects to individuals could occur across multiple months.
		Long-term	
	Geographic Extent	**Local**	When the total area ensonified above behavioral harassment thresholds (160 dB for seismic and 120 dB for drilling) is considered (Table 4.5-14b), the impacts are local.
		Regional	
		State-wide	
	Context	**Common**	Not ESA-listed. Population status not well known for Chukchi but thought to be stable or increasing in Beaufort. Few overlaps with feeding areas, and wide migratory corridor likely not heavily impacted by activities.
		Important	Some activities may overlap known migratory corridor, and activities may occasionally impact important feeding areas.
		Unique	
Injury and mortality	Magnitude or Intensity	**Low**	Injury or death highly unlikely
		Medium	Though highly unlikely, cannot rule out PTS
		High	
	Duration	**Temporary**	
		Long-term	Though highly unlikely, PTS would be permanent if incurred.
	Geographic Extent	**Local**	Since unlikely, any few impacts would be considered local
		Regional	
		State-wide	
	Context	**Common**	Not ESA-listed, populations not thought to be decreasing
		Important	
		Unique	